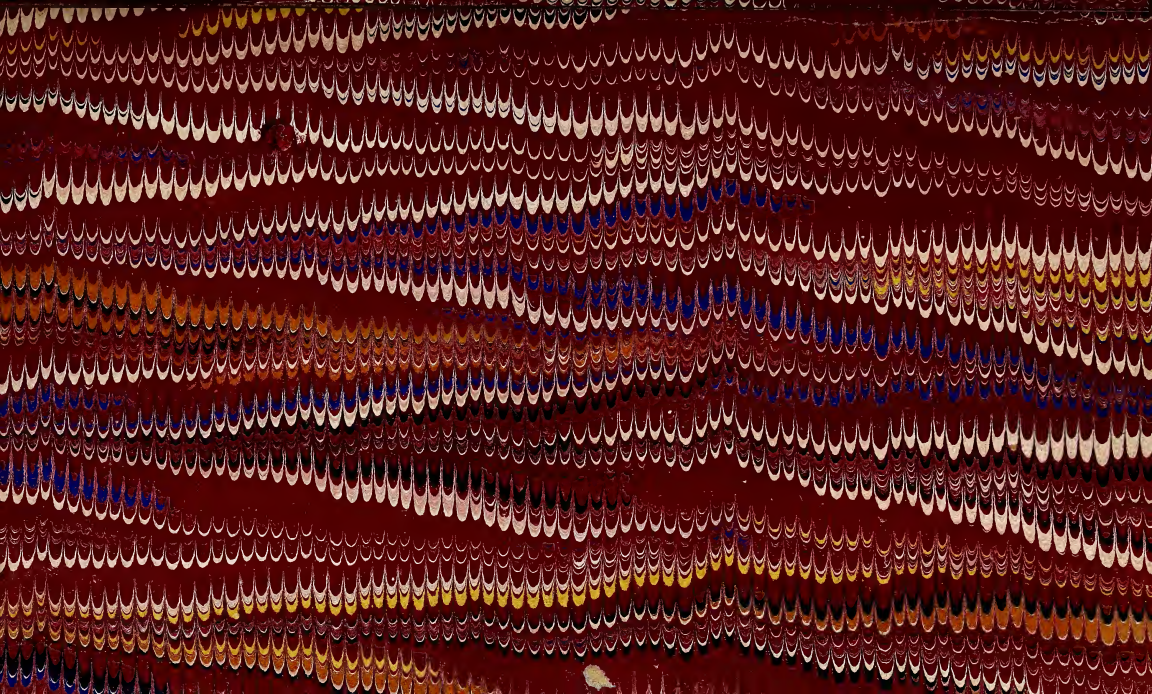


In Parliament—Session 1846.

THE

PETITION OF ALEXANDER BAIN

AGAINST, AND THE

EVIDENCE BEFORE THE COMMITTEE

ON, THE

ELECTRIC TELEGRAPH COMPANY BILL.

LONDON:
CHAPMAN AND HALL, 186, STRAND.
1846.

C. WHITING, BEAUFORT HOUSE, STRAND.

CONTENTS.

TO THE

HONOURABLE THE COMMONS OF GREAT BRITAIN AND IRELAND,

IN PARLIAMENT ASSEMBLED.

The Humble Petition of Alexander Bain, of Edinburgh, Electrical Engineer, and Electric Clock and Electric Telegraph Manufacturer.

SHEWETH,—

THAT in the year 1838 your petitioner invented an Electrical Clock of such construction as to shew the hour indicated by an ordinary clock placed at a distance from it, and connected with it by a voltaic circuit merely.

That previously to the month of June, 1840, your petitioner also invented an Electrical Telegraph, capable of printing messages at distant places, by means of a voltaic circuit, which your petitioner insists was the first invention, whereby that important object could be effected.

That on the 1st day of August, 1840, your petitioner being then a poor man, and in want of the means of turning his said invention to profit, called upon Charles Wheatstone, Esq., professor of experimental philosophy at King's College, London, and explained to him your petitioner's invention of an Electric Clock, and his invention for printing a message transmitted by an Electric Telegraph, and sought his the said Charles Wheatstone's assistance for

the furtherance of the said inventions; but the said Charles Wheatstone, instead of affording your petitioner such assistance, shortly afterwards endeavoured to deprive him of the merit and benefits of his aforesaid discoveries, and opposed his application for a patent for his invention of a printing telegraph as hereinafter mentioned.

That on the 8th day of January, 1841, your petitioner obtained a patent for an Electrical Clock, and in the subsequent month of September he, in conjunction with Lieutenant Wright, R.N., applied for letters patent for an Electrical Printing Telegraph, and other things.

That the said Charles Wheatstone opposed the grant of the said last-mentioned letters patent to your petitioner, and stated to the then attorney-general, Sir Frederick Pollock, that one objection contemplated by a patent of him, the said Charles Wheatstone, then in progress (being the letters patent granted to the said Charles Wheatstone, of which the specification was afterwards enrolled on the 7th day of January, 1842), was a plan to enable a man in London to print a letter in Edinburgh, and thereupon the said Sir Frederick Pollock refused to permit the patent of your petitioner to pass; but the said Sir Frederick Pollock having subsequently discovered that the said Charles Wheatstone had deposited with Sir John Campbell, the predecessor of him, the said Sir Frederick Pollock, a general statement of the nature of the inventions comprised in the said last-mentioned letters patent of the said Charles Wheatstone (of the fact of which deposit having been made, the said Charles Wheatstone had not informed the said Sir Frederick Pollock), and the said general statement having been examined, and found to be wholly silent on the subject of a Printing Telegraph, the said Sir Frederick Pollock then permitted your petitioner's last-mentioned letters patent to pass, and the Great Seal was affixed thereto accordingly, and your petitioner insists that the inventions comprised in the said last-mentioned letters patent, as well as the said letters patent for an Electrical Clock, were wholly original, and in no respect infringements or an infringement on any previous invention.

That about the same time your petitioner, by his own

experiments, discovered the, till then, unknown property of water or moist earth, to convey a voltaic current when the connecting insulated wire only ran one-half of the circuit, and that he sought to secure such his invention by his said letters patent of the 7th day of December, 1841, and the same was included in and claimed by him by his aforesaid specification of the inventions comprised in such letters patent, enrolled on the 7th day of June, 1842.

That about the same time your petitioner publicly exhibited his said invention, and the same was noticed by and described in several publications of the day.

That afterwards, on the 8th day of September, 1842, William Fothergill Cooke, of Blackheath, in the county of Kent, Esquire (and who was then a partner of the said Charles Wheatstone, under certain letters patent relating to Electric Telegraphs, but of which your petitioner insists his aforesaid inventions were in no respect infringements), obtained another patent in the specification, whereof he claimed the use of the property of the earth or water to complete the voltaic current which had been discovered by your petitioner as aforesaid, and which was specified by him in the preceding month of June as aforesaid.

That afterwards, on the 10th day of October, 1842, your petitioner, by his own experiments, made the further and most important discovery that the earth itself, or the moisture thereof, possessed the property of generating Electric Currents of very considerable force, by means of two plates of different metals (as for example, zinc and copper), without the assistance of any galvanic battery whatsoever, which discovery, and the application thereof to various useful purposes, including the improvement of Electric Telegraphs and Electric Clocks, your petitioner then sought to secure to himself by letters patent, which he then sued out for that purpose, dated the 27th day of May, 1843.

That shortly before your petitioner made his last-mentioned discovery, he also discovered that a derivative voltaic current might be obtained from a voltaic current passing through a wire without making any interruption

in such wire, by merely fixing the ends of two smaller wires, at some distance from each other, to the main wire, and bringing the other ends of such small wires into contact, and your petitioner, in his specification of the inventions comprised in his said last-mentioned patent, described the application of his said last-mentioned discovery to the working of Electrical Clocks, at different intermediate points along a main wire conveying an electric current.

That your petitioner, previously to the date of the said last-mentioned letters patent, also invented an Electrical Telegraph capable of producing a sufficient number of signals by means of *a single voltaic circuit*, acting on a vibrating magnetic pointer; whereas the said Charles Wheatstone and William Fothergill Cooke had in all their previous inventions for Telegraphs by means of vibrating magnetic pointers, employed *several voltaic circuits.*

That the said last-mentioned invention of your petitioner combined with his said invention for transmitting a voltaic current through a single conducting wire, and his said invention for producing a voltaic current, by the action of the earth, was included in the said letters patent, dated the 27th day of May, 1843, and (as described in the specification of the inventions comprised in the same letters patent) constitutes the cheapest as well as the most simple and convenient Electrical Telegraph which has yet been discovered.

That owing to the influence of the said Charles Wheatstone and William Fothergill Cooke, your petitioner has not yet had an opportunity of permanently setting up and working any Electric Telegraph in England, but your petitioner has set up and has now constructed, on the principle of his last-mentioned invention, an Electric Telegraph in operation between Edinburgh and Glasgow, a distance of 46 miles, which Telegraph is now working to the entire satisfaction of all concerned, and to the great advantage of the community.

That your petitioner exhibited a Telegraph constructed according to his last-mentioned invention, worked as well by a voltaic battery as by a voltaic current produced as

aforesaid from the earth, and also his Printing Telegraph, on the South-Western Railway, between Nine Elms and Wimbledon, in the county of Surrey, in or about the month of May, 1844, in the presence of some of the Lords and Secretary of the Admiralty, and of several Members of your Honourable House, and his said inventions thereby, or by means of the specifications under your petitioner's said several patents, became known to the said Charles Wheatstone and William Fothergill Cooke, who have since sought to appropriate to themselves the merits and benefits of several of the last-mentioned inventions.

That subsequently, and in the summer of the year 1844, your petitioner conceived the notion of conveying signals by means of symbolic sounds produced by a voltaic current, in addition to visible symbols, and, for the purpose of carrying such idea into effect, your petitioner employed a mechanic to manufacture certain bells capable of producing different and easily distinguishable tones, and your petitioner was otherwise engaged in the year 1844 in perfecting such his invention, with the view to the using of it as an improvement of his last aforesaid invention for Electric Telegraphs, and your petitioner in the same year made such his invention of telegraphic communication by means of symbolic sounds known to several of his friends; but in the spring of 1845, and before your petitioner had proceeded to secure such his invention by means of letters patent, your petitioner discovered that the said Charles Wheatstone and William Fothergill Cooke were applying for letters patent "for certain improvements in Electric Telegraphs, and in Apparatus relating thereto," and that their petition for such letters patent had been referred to her Majesty's then Attorney-General, Sir William Webb Follett, now deceased.

That your petitioner conceiving that such letters patent might relate to some invention having reference to symbolic sounds, and might tend to prejudice your petitioner in the use of his last-mentioned invention for the employment of symbolic sounds in Electric Telegraphs, entered a caveat against such patent, and accordingly your petitioner and the said William Fothergill Cooke were separately

heard upon your petitioner's opposition to such patent, before the late Sir William W. Follett, in the month of April last, when, owing to the absence of any claim or any intelligible claim of an invention for telegraphing, by means of symbolic sounds, in the deposit or general statement of the nature of the invention for which the said Charles Wheatstone and William Fothergill Cooke sought the said letters patent, the Attorney-General disallowed the opposition of your petitioner, your petitioner's then opposition being confined, owing to his unavoidable ignorance of the objects for which that patent was sought, to his invention of the use of symbolic sounds, and, accordingly, the said Charles Wheatstone and William Fothergill Cooke afterwards obtained letters patent under the Great Seal of Great Britain and Ireland, bearing date on or about the 6th day of May last, for improvements in Electric Telegraphs and in apparatus connected therewith, under and in pursuance of which they subsequently, on the 6th day of November last, enrolled a specification, thereby claiming, among other unimportant alleged inventions, not only the use of symbolic sounds, but likewise the use of your petitioner's aforesaid invention of an Electric Telegraph in which a single voltaic current only is employed, combined with his invention for completing a voltaic current by means of a single wire only, and also his invention of forming derivative currents without interrupting the main wire, applied to Electric Telegraphs, such last-mentioned claims being, as your petitioner insists, *an obvious piracy of your petitioner's said inventions* protected by his said letters patent of the 7th day of December, 1841, and the 27th day of May, 1843.

That in the summer of 1845, the said Charles Wheatstone and William Fothergill Cooke likewise petitioned for letters patent for Scotland, "for certain improvements in Electric Telegraphs and in apparatus relating thereto," being the same inventions for which they had sought and obtained as aforesaid an English patent, which last-mentioned petition being referred to the Lord Advocate for Scotland, your petitioner entered a caveat against such their application, and subsequently the Lord Advocate having heard your petitioner and likewise the said Charles

Wheatstone and William Fothergill Cooke, on your petitioner's opposition (which was the same as that urged before the late Sir William Webb Follett, and for the like reasons confined to the invention of symbolic sounds), was then pleased to allow your petitioner's opposition so far as the said Charles Wheatstone and William F. Cooke had sought to patent the use of symbolic sounds, but allowed their petition as to the other alleged inventions, to which your petitioner's opposition did not extend, and thereupon the said Charles Wheatstone and William Fothergill Cooke obtained letters patent for Scotland for their said last-mentioned inventions, bearing date the 3rd day of July last, under which they have since, in the month of January last, enrolled a specification in Scotland, and such specification being in all respects similar to their said specification, enrolled in England on the 6th day of November last, the said Charles Wheatstone and William Fothergill Cooke, have thereby not only *in fraud of your petitioner, but in disregard of the Lord Advocate's express disallowance thereof*, unduly claimed the exclusive use of their said alleged invention of symbolic sounds, and have also thereby laid claim to your petitioner's said several other inventions.

That subsequently, in the month of October last, the said Charles Wheatstone and William Fothergill Cooke obtained other letters patent for Ireland, bearing date the 22nd day of October last, for the like invention, but on your petitioner's opposition in Ireland against such patent, a compromise or arrangement was come to between him and the said Charles Wheatstone and William Fothergill Cooke, whereby the right of making use of symbolic sounds on Electric Telegraphs in Ireland was expressly reserved to your petitioner, but your petitioner still remains in entire ignorance of the nature and contents of the specification which the said Charles Wheatstone and William Fothergill Cooke have enrolled in Ireland under their last-mentioned patent.

That your petitioner not having been in England between the months of October and January last, remained in entire ignorance of the nature and extent of the specifications and claims of the said Charles Wheatstone and

William Fothergill Cooke, under their aforesaid patents for England and Scotland respectively, until after they had enrolled their aforesaid specification in Scotland, and until the 19th day of January last, when your petitioner visited London for about forty-eight hours, and inspected their specification enrolled in England, and when your petitioner immediately instructed his solicitor to institute proceedings to invalidate the aforesaid English patent of the said Charles Wheatstone and William Fothergill Cooke for the causes aforesaid, and accordingly so soon as your petitioner's solicitor could procure a copy of their last-mentioned specification, and prepare the requisite instructions for counsel, such instructions were laid before counsel for his consideration and advice, and to prepare the necessary or proper process for disputing the validity of the aforesaid patents of the said Charles Wheatstone and William Fothergill Cooke.

That after so instructing counsel, your petitioner from the newspaper reports of the proceedings in parliament, for the first time discovered that a company had been or was about to be formed to be called "The Electric Telegraph Company," but excepting from the Bill which has since been brought into your Honourable House, in which the name of the said William Fothergill Cooke and also of John Lewis Ricardo, Esquire, a Member of your Honourable House, occur as hereinafter, is more particularly mentioned, your petitioner still remains in entire ignorance if any such Company has been actually formed, and of whom such Company consists, or who are the promoters thereof, the project for the formation of such Company having been provisionally registered according to the Act for that purpose, in the names of the said William Fothergill Cooke and Robert Wilson, his solicitor, only as the promoters thereof, but the provisions of that Act have not otherwise than by registering advertisements been in other respects duly complied with.

That a Bill has been recently brought into your Honourable House, entituled "A Bill for Forming and Regulating the Electric Telegraph Company, and to enable the said Company to work 'certain letters patent,'" whereby,

after reciting several letters patent, and among others the aforesaid several letters patent sued out by the said Charles Wheatstone and William Fothergill Cooke for England, Scotland, and Ireland, for certain improvements in Electric Telegraphs and in apparatus relating thereto, and that in each of the said letters patent is contained a condition or proviso against the said letters patent respectively, or the privileges, benefits, and advantages thereby respectively granted becoming vested in, or in trust, for more than twelve persons, or their representatives, at any one time as partners, dividing or entitled to divide the benefits or profits obtained by reason of the same letters patent respectively, and furthermore that the said several inventions have been found to be of great public benefit and utility, and that it is desirable that the same should be brought into more extensive use, and that that object would be greatly promoted if the said patent privileges were permitted to be vested in a company consisting of more than twelve persons, with the powers and other provisions thereinafter contained, but that the same cannot be effected without the aid and authority of Parliament; it is by the same Bill proposed to be enacted, that the said William Fothergill Cooke, John Lewis Ricardo, Esquire, M.P., and all persons and corporations who have already subscribed or shall thereafter subscribe to the undertaking therein mentioned or referred to, their executors, administrators, successors, and assigns respectively, shall be united into a company for the purposes therein, and in the Land Clauses' Consolidation Act, 1845, and the Companies Clauses' Consolidation (Scotland) Act, 1845, mentioned, by the name of "*The Electric Telegraph Company*," and by that name shall be a body corporate with perpetual succession, and shall have power to purchase and hold lands for the purposes of the undertaking, with the restrictions therein and in the said Acts mentioned and contained, and with such other enanctments, and subject to the provisoes which are in the said Bill mentioned, and which, on reference thereto, will more fully appear.

That your petitioner humbly insists, and submits to your Honourable House, that the recitals in the said Bill,

whereby it is alleged that it is desirable that the said several patents, in the said Bill mentioned, should be brought into more extensive use, are untrue, for that the same, with the exception of the said several patents hereinbefore particularly mentioned, being those for certain improvements in Electric Telegraphs and in Apparatus relating thereto, *so far as they are in piratical violation of your petitioner's patented rights* as hereinbefore mentioned, *have become valueless, or of but small value,* by *reason of the more useful inventions of your petitioner,* and are consequently not deserving of Parliamentary encouragement, and for the reason aforesaid, and inasmuch as the said several patents for improvements in Electric Telegraphs and in Apparatus relating thereto are as aforesaid piratical, and are now about to be the subjects of judicial discussion: your petitioner humbly insists and submits to your Honourable House, that the said Bill ought not, pending such litigation, to pass, and that nothing should be enacted with reference to the matters aforesaid, which shall or may in anywise tend to the prejudice of your petitioner, or his rights as such inventor and patentee as aforesaid.

Your petitioner submits to your Honourable House, that the means of Electric Telegraphic communication are so important, that it is, doubtless, the wish of the legislature to encourage all attempts to carry this most useful art to perfection, of which, however, it is at present very far short, if considered as a vehicle of social correspondence.

That notwithstanding the manifold piracies of the said Charles Wheatstone and William Fothergill Cooke committed on your petitioner's invention, as hereinbefore detailed, the state of the art in the hands of those persons is still in a very low condition, and, out of all comparison, behind certain new improvements in Electric Telegraphs, for which your petitioner has obtained other letters patent, dated on the 25th of September last, and the specifications of which must be enrolled on the 25th day of this March instant.

And whereas the said Charles Wheatstone and William

Fothergill Cooke have only as yet advanced so far as to make a limited number of signals in a very unskilful and unscientific manner, your petitioner is prepared to prove before any Committee of your Honourable House, that a single portion of his new inventions is capable, by the most rapid motions, of indicating with precision, and without doubt, any one word that may be required out of thirty-five thousand words at pleasure ; such is the power of this part of his said new invention, but which is combined with many other improvements of the utmost value: and your petitioner, therefore, humbly trusts that your Honourable House will deem it to be an injury to the community at large to pass an Act which will virtually exclude your petitioner from fair and honest competition in the art of constructing Electric Telegraphs, by conferring the great powers requested on a company who cannot, without the most flagrant piracy of such your petitioner's invention, come in any way near to the advanced state to which your petitioner has already carried that most useful art.

Your petitioner, therefore, humbly prays, that the aforesaid Bill may not pass your Honourable House, and that your petitioner may be heard by his counsel, agent, and witnesses, before the Committee to which such Bill may be referred, in opposition to the preamble, and such clauses thereof as affect the interest of your petitioner.

And your petitioner will ever pray, &c.

(Signed) ALEXANDER BAIN.

EVIDENCE BEFORE THE COMMITTEE

ON THE

ELECTRIC TELEGRAPH COMPANY BILL.

HOUSE OF COMMONS,

JOVIS 19t DIE MARTII, 1846.

(CAPTAIN BOLDERO IN THE CHAIR.)

Mr. M. D. Hill and Mr. Hindmarsh appeared as Counsel in support of the Bill.

Messrs. Dyson and Hall, Agents.

The Petition of Mr. Alexander Bain against the Bill was read.

Mr. Birkbeck and Mr. Webster appeared as Counsel for the Petitioner.

Mr. M'Dougall and Co, Agents.

Mr. HILL opened the Case on behalf of the Promoters of the Bill :—Sir, I have the honour to appear before this committee on behalf of the promoters of a Bill, the short title of which is to be, "The Electric Telegraph Company's Act." I shall detain the committee as briefly as I can, knowing the great mass of business which presses on the attention of all members of parliament; but it will be necessary for the understanding of the case that I should for a few moments call your attention to the nature of the invention which it is the object of this Bill to give facilities for spreading throughout the country. Probably honourable members are aware that as early as the year 1837, by the talents of two gentlemen now well known in the world, Mr. Cooke and Professor Wheatstone, all difficulties had been overcome, and a working electric telegraph had been constructed. The telegraph has probably been seen in operation by all the members of the committee. It would occupy too much of your time if I were to go into

much detail as to its construction. It may suffice to touch on its principle. Gentlemen are perfectly aware that magnetism, electricity, and galvanism are found by philosophers to be one and the same principle, modified in action, brought into action by different means, but, in truth, the same principle. The movements of the telegraph may either have their origin in a galvanic battery, or in a great magnet, but the battery or magnet whichever is used is so placed that a wire, or series of wires, are submitted to galvanic or magnetic action, and by ingenious contrivances, through which the galvanic or magnetic current is stopped or deflected, it is made to subserve different purposes. Needles are set in motion upon their centres through the wires, as a medium of communication at any distance from the operator, and the electric or galvanic motion is so rapid that I believe it outstrips the rapidity of light, which we are told by scientific men travels from the sun to the earth in a space of time somewhat short of eight minutes, if I have not forgotten my schoolboy learning. Now this is rapid enough for all practical purposes, and therefore whatever other defects may be discovered, the want of rapidity, I am sure, will not be one of them. Indeed this was exemplified in a very curious manner by an experiment, that members may or may not have heard of, performed on the telegraph of the Great Western Railway, where this telegraph has been laid down for a long time so far as from the station at Paddington to Slough. A message was despatched from Paddington on the 1st of January, and Slough being directly to the westward, was received there on the 31st of the preceding December, which is easily understood when it is recollected that the motion of galvanism is far more rapid than the diurnal motion of the earth. Sir, this is to use the telegraph as a toy. I need not however say that the powers of the machine are competent to effect objects of the highest social and commercial importance.

The Electric Telegraph—the first patent for which was taken out in the year 1837—was laid down for experiment first I think on the Great Western Railway, where I myself had the pleasure of seeing and hearing a very clear and intelligent description of it given by Mr. Cooke, in October, 1839, and I can myself testify that it was then working with a marvellous degree of celerity and certainty. In the year 1840 it was made an essential incident to the working of the Blackwall Railway. The Blackwall Railway, as honourable members may know, is worked in a peculiar manner; not by locomotive engines, but by what is called a tail-rope, or a rope passing over a cylinder or drum at the one end of the railway, and at the other another cylinder or drum, which drums are set in motion by steam-engines.

Now, sir, the arrangements of the Blackwall Railway are such that if this telegraph were out of order the railway itself would be out of order—if you cannot work the telegraph you cannot work the railway. This results from the circumstance of there being inter-

mediate stations which are to be accommodated necessarily by the same rope, and therefore unless the carriages are all attached to the rope at the same time—I don't mean at the same instant—but unless when a signal is given it is found that all the carriages are attached or detached, as the case may require, confusion and accident, and the stoppage of the railway may be the result. These stations are spread up and down the line, it is therefore necessary you should have a communication at one mile, two miles, or three miles, and that that should be under the control of a person sitting in a room, at the one or other end of the railway, or at the intermediate stations. It is, I think, abundant proof of itself, if nothing else had existed, of the perfection to which the Electrical Telegraph was quickly brought, that from the year 1840, in which the telegraph was made, as I say, a component part of the Blackwall Railway to the present time the railway has been worked with unerring exactitude.

This period of time is surely of sufficient length to test not merely the scientific accuracy but the practical utility of this invention, for honourable members well know that many feats of science can be performed which are very wonderful and very beautiful, yet when they are to be applied to the rough-working daily use of commerce, they utterly fail and become absolutely nugatory. That is not so with the Railway Telegraph.

Sir, it has been applied in another way, in which I hope and trust it will be rapidly extended. Railways are constructed at enormous cost. Where the traffic is not sufficient they have been of late constructed with a single line of rails, but it is very obvious that unless those single lines be very carefully worked, there is great danger of stoppage, if not of collision, from the trains meeting in an opposite direction. It is quite clear therefore for the management of such railways some set of signals which should enable you to know what is going on at every part of the line while standing at one end of it, is very important. There is a railway established from Norwich to Yarmouth, a single line, which is worked by means of the telegraph, and worked with very great facility.

The patents for this invention and its improvements belong to Mr. Cooke, with one or two other persons. Mr. Wheatstone, a gentleman whose mind is absorbed in science, having been, to use a common expression, bought out, Mr. Cooke, and those who act with him, are now engaged in laying down Electrical Telegraphs upon some eight or ten railways at this present time. I have a list before me. They have laid down, as members are probably aware, an Electric Telegraph on the South-Western Railway from the Nine Elms to Gosport or Portsmouth. This was done at the wish of government, and mainly for the purposes of government, and it is, or will, when it is completed in the manner I shall point out, and which will suggest one of the reasons why we come for this Bill, be

of immense service to the government, and utterly supersede the use of the Semaphore. At present it only comes towards London as far as Nine Elms, and there is the vacant space between Nine Elms and the Admiralty, which I need not say is productive of very considerable delay and inconvenience; but the power of the telegraph, its command of language, of combinations which may be used alphabetically, or according to the code of signals which has been so long established at the Admiralty, is unlimited. The Queen's speech, at the opening of the present session, was telegraphed *in extenso* from Nine Elms to Portsmouth in an incredibly short space of time.

But, sir, I am now coming to the difficulties under which this invention at present labours. I have mentioned that the railway-communication on the South-Western Railway stops at Nine Elms. To continue it into town, there is required a similar power to that possessed by every Gas Company, and every Water Company, of opening the streets, for the purpose of introducing the tubes containing the wires of communication; and when that is done, a small room in the Admiralty will be the eye and the ear which may receive instant information of every proceeding in Portsmouth harbour. The South-Eastern Railway Company have now put down a telegraph to Dover, which may be connected with the Admiralty in the same way, and then the eye and the ear, in this little room, will see, in addition, what is going forwards at Dover, or in the Straits, or on the coast of France. And so, by multiplying these connections of wires, bringing them all to a central office, it is quite evident that the whole of the vast area of this island may be, for purposes of intelligence, compressed into one chamber.

Sir, the convenience, nay, even the necessity, for purposes of government, for purposes of commerce, for purposes of general intelligence, of completing the grand effects of this discovery by means, such as I have, in part, pointed out, and, as I shall point out, are so obvious, that the parties, when they had completed their plan, were determined to come to Parliament.

Sir, that plan is as follows:—They propose to lay down lines of wires for the purposes of railways. That is, railway purposes are one object; those railway purposes to be accomplished by wires, I have partly adverted to; but upon all lines, Members will see they are exceedingly important. Many collisions, producing fatal accidents, may have been prevented, if the Electrical Telegraph system had been complete upon the railways where they happened, because a collision very frequently, nay, generally, happens thus: the engine drawing the train fails for some reason; the train stops, or it goes on more slowly than is expected. One would suppose that it was not very easy to "run into a train," as it is called, with another train, but I suppose there must be some difficulty in estimating the distance, because we find that even in the open day, and at night when there are lamps, it is a misfortune that frequently occurs, not to one train or to two, but to many.

Now, sir, if there were means of carrying information at every station, that the speed was slackened, or altogether stopped, much valuable life might have been saved, many very tremendous accidents might have been spared. The invention is now, by slow degrees, brought to that perfection that an apparatus may be given to every guard upon a railway-train, which will enable him to get down, and, touching with his instrument the portion of the wires where the train happens to be, thus communicate intelligence of a stoppage to and fro, up and down the line in a second of time, informing every part of the railway what has taken place.

Now, sir, as to the plan for carrying these great objects into effect. It is proposed by the gentlemen, whom I have the honour to represent, that there should be a great central office in London, of the nature of a post-office, except that the intelligence would be by words—they are the flying words, the *epea pteroenta*; they are not written down—it is the same as if a code of signals were used; they are not letters, and the intelligence, therefore, travels more swiftly.

But it is hoped, in the course of time, to make the establishment as diffusive and as extensive as the system of the post-office itself. To effect that object, the analogy holds good, as there is a great central post-office in London, so are there branch offices in every town in the island, and there must be telegraphic-offices of the same kind in the various towns. It is proposed, as part of the present plan, to erect something like a thousand, I think, at least a very large number, I may have exaggerated the number they hope to be able to found, but it is very considerable.

Sir, by this time, I think, the Committee will be aware there is one agent which we shall be obliged to bring into operation, and which no discovery has yet superseded. We have superseded horses by steam, and we have superseded the Semaphore by electricity; but there is one agent which seems to increase in importance the further we proceed in our course of discovery, and that is—money. Money is the agent we must employ for the foundation of the great scheme I am laying before you. It is estimated that a capital of 600,000*l.* will be required, with, I think, even the power to borrow to some further extent. In order to raise a capital like this, it is quite necessary men should combine—no one man, no two men, no three men, can be expected to embark such a capital as that in any undertaking. One necessity, therefore, for a Company, arises from the great capital that will be required. Another necessity arises from the powers with which it will be essential to arm the Company, for the purpose of enabling them to carry into effect their objects. They must have power under proper superintendance, and under all those guards and restrictions which are placed upon Gas Companies and Water Companies, of opening the streets, and they must have certain other powers mentioned in the various clauses of the Bill, and with which I will not detain the Committee, for the purpose of effecting their intentions. These powers it is not

usual, and, indeed, it would not be right, to intrust to a private individual. They are vested, by the common course of legislation, in Companies.

But, sir, there is another reason why we should have an Act. It is known by Members to have been a very ancient practice, up to within a very few years, that inventors taking out patents were prohibited by the patent itself from assigning their patent to more than five persons; so that no more than five persons could be owners of a patent. What was the origin of this restriction I do not know, but it remained up to the time of the attorney-generalship of Sir John Campbell. Sir John Campbell, however, advised the Crown not to throw aside the restrictions altogether, for reasons which, I dare say, were very excellent, though I know not what they were, but to increase the limit from five to twelve. At present, therefore, twelve persons may be interested in a patent, but not more than twelve. It is quite clear, that in order to work this great plan, more than twelve persons must combine; and, therefore, we must ask, as has been done before, for the powers of an Act of Parliament. Indeed, it is now almost a matter of course to grant Bills such as the present.

Sir, this being so, the Bill was prepared, and probably the Committee is aware that such Bills are now submitted, in due course, to the Board of Trade, in order that that Board may see whether they ought to pass or not; that has been done in the present instance, and the Board of Trade see no objection to our Bill passing. I think I may state, that this is by no means an unprecedented proceeding. Within the last twenty years there have been many such Bills, and it has been felt by Parliament, that whenever an invention is very important, it ought to be worked by a Company, private individuals not having the means, even where they do not require extraordinary powers. In our case, the power of breaking up the pavement is required, and unless we have that power, the plan cannot be carried into operation. Hitherto it has been thought right to grant Acts of Parliament of this kind.

Then, sir, we ask to have the means for the purposes of the government, for the purposes of the public, of effecting what we have been aiming to do, and what we have in so great a measure accomplished, even by our own unaided exertions. I will say the Bill contains every necessary provision for providing against privileges confided to private individuals being used contrary to the advantage of the public. The Company where it is incorporated and formed by this Bill, will not have the usual benefit of an incorporated body, of being free in their private capacity from the responsibility of the debts of the concern, but every shareholder will remain to the whole extent of his property, liable to every creditor of the concern. This is especially provided for. Then again, inasmuch as we ask for powers, we are prepared, and clauses are drawn for the purpose, to make it imperative upon the Company to grant to any parties re-

quiring it, their aid, in establishing a telegraph. The government may require them to lay down a telegraph, railway companies may require them to lay down a telegraph; the government is placed in this matter on exactly the same footing as it is with regard to the Post Office. For honourable members recollect that railway companies are bound to carry the mails for the Post Office, and if they cannot agree with the Post Office functionaries upon the remuneration, arbitrators are called in to determine it. That clause has been copied into the present Bill, *mutatis mutandis*, as applied to the Electric Telegraph.

Sir, these are the grounds on which I humbly beg you to pass this Bill. This Bill, however, is opposed; it is opposed by one gentleman, and, I believe, by no more. That gentleman is a person of the name of Bain, and he asks permission to show you that this Bill ought not to pass. Now Mr. Bain has put a petition on the table, which, if the facts of it are true, would be highly discreditable to the gentlemen whom I have the honour of representing, and they therefore feel a very natural wish to meet Mr. Bain, to give him an opportunity of proving any charge which he has made, in the full confidence of being able to rebut it. But, sir, I have felt that I owe some duty to the committee, as well as to my clients, and therefore I am bound to state that it does not appear to me that Mr. Bain has made any allegation in his petition, which you are the tribunal to try. If, however, you should be of a different opinion, we shall have the honour of attending you a considerable time, an honour I shall esteem very highly; and I dare say the matters that will be examined into will be highly interesting, and more so than they usually are, because they relate to matters of science, and to matters of very great curiosity; but I do not know that that interest and that curiosity will quite repay honourable members for sitting here for the next fortnight or the next month. They will have to determine whether he shall be heard when they shall be in possession of what has been said by my friend, who appears for Mr. Bain, in support of his right to be heard at all.

It seems to me that Mr. Bain has fallen into a not unnatural mistake for a gentleman not conversant with law to make. He supposes that his legal position would be changed by this Bill; now this bill will place certain patents, which are now in the hands of private individuals, in the hands of a company, but the Bill will not operate to make the patents good if they are bad. The Bill will leave the patents just as open to inquiry in courts of law or equity as they are now; and if Mr. Bain is correct in saying that he is the true discoverer, that Messrs. Wheatstone and Cooke are clever persons, not for inventing matters, but for taking hold of the invention of others—if he is right in those allegations why the law is quite strong enough to protect him. He may bring his action against them for piracy; he may bring his actions against any person to whom they assign their patent, they may assign their patent

now to me without the aid of a Bill. If I use the patent so assigned to me, I am just as much open to Mr. Bain's attack as Messrs. Cooke and Wheatstone. Again when the Bill enables Messrs. Cooke and Wheatstone to assign their patents to a company, that company will be just as much open to attack as the original inventor. Why, therefore, you should be troubled with the matter, I know not; I should be very glad, I say, to examine it before you, because these gentlemen feel that it is not at all pleasant when attacked, to shrink and say this is not a proper tribunal; they feel desirous of creating a tribunal the moment the charge is made to inquire into it.

Then you, the Committee, will consider what would be the consequence of this inquiry. What would become of it if it were entered into? Your determination would bind neither party. Suppose you were to say by your decision, Mr. Bain's allegations are good, these are piracies of Mr. Bain's patent: well, the promoters, the owners are not bound by that. If the jury and judge should come to a different conclusion, if a Court of Equity should come to a different conclusion, wherever this question was tried, whether in law or in equity, what this committee might have said on the subject of the validity or invalidity of the patents, I am bound to say with all respect, would stand for nothing at all. If you were to decide in favour of the Company, Mr. Bain, on the other hand, would not be at all bound or damnified. He could still bring his action, or repeal the patent by *scire facias*, if so advised. He could bring his action for piracy, or go into Chancery, and move for an injunction. All those remedies would be open to him after investigation, as they are now.

Sir, I will not, till I hear from my learned friends the grounds on which they claim to be heard before you upon this matter, enter further into the question. You see I have cautiously abstained from saying whether Mr. Bain is right or whether Mr. Bain is wrong. As I do not choose at this moment to admit this is a matter to inquire into here, I think it would be wrong for me to pronounce any opinion upon it; but it will remain for my learned friends to show on what ground it is they say Mr. Bain has a right to proceed in his opposition to this Bill when his legal position is not at all changed. Why do you permit a landlord to come and oppose a railway bill? Because a railway bill seeks to change his legal position. He has a right to his land against all the world. When the railway bill becomes a law, the company have a right to call on him compulsorily to give up that land, he receiving a remuneration. Well, then he has a right to be heard. We do not seek to interfere with Mr. Bain at all.

With these observations I shall sit down, and shall proceed in the first instance to prove the mere formal parts of the case. If my friends attempt to take any part in it, then I shall raise the question as to their right to be heard.

Mr. BIRKBECK—As I shall certainly feel it my duty to put some questions to the witnesses called by my learned friend to establish his case, with your permission, sir, I would at present proceed to state the reasons why it appears to me my client has a *locus standi* in the Committee.

Mr. B. HAWES —Would it not be more formal to call a witness and to put some question to him that involves another, because then it would appear on our minutes regularly that you objected, otherwise we shall have nothing on our minutes.

Mr. Edward Cowper was then called and examined by Mr. Hindmarsh; and upon Mr. Birkbeck putting a question to the witness,

Mr. HILL said, Now I object to my friend asking the witness a single question. He has no *locus standi* here, and he will have the goodness to show the Committee the right which he has to appear.

Mr. BIRKBECK—Sir, I have the honour to appear for Mr. Bain, and I regret that he does not appear by a counsel more acquainted with Parliamentary proceedings than I am. He possesses no capital or connexions, except what have been created by his own great talents and inventive genius. So circumstanced as he is, I am sure that you will feel inclined, certainly not to lean against him, but rather to lean in his favour.

Sir, my learned friend has stated very eloquently the great advantages of the Electric Telegraph. I am not here to dispute them. I believe that he has not in the slightest degree exaggerated their importance, but it appears to me he has failed in proving the necessity or the utility of forming such a company as this Bill endeavours to form. It appears to me more than doubtful, if you will examine the clauses which this Bill contains, whether, instead of its being of advantage to the public, that such a company should be formed—

Mr. HILL—My learned friend will forgive me for interrupting him; he is entering into the merits of the Bill; at present he is a little irregular, if he will allow me to say so. The question before the Committee is as to Mr. Bain's right to discuss those merits. Let me admit, for the sake of argument, there are no merits, the question is, has Mr. Bain a right to appear and discuss that before you.

Mr. BIRKBECK—Sir, I carry the argument a little further than my friend. Suppose I say this Bill is positively detrimental—positively injurious—to the public, and Mr. Bain, humble individual as he may be, is one of the public, and as one of the public alone, supposing he had no other interest in the case, I submit he has a right to be heard here.

My learned friend has referred to the case of railway bills, in which landowners alone are permitted to oppose; but why is that rule adopted? Because it is supposed that there are not a sufficient number of landowners on a line through which a railway

is permitted to pass? There are a sufficient number of them whose property is physically affected by the railway in order to render them the representatives of the interests of the public. But if my client is not permitted to oppose this Bill, then no one can be permitted to oppose it. Will it be argued that this is a Bill which is to pass without any one being permitted to offer opposition to it? My friend has stated that the whole is to be compressed into a central room. All the intelligence received at the out-ports is to be known at the same instant; it is communicated in the room which is to be the central office of the Company. Is not this a most important fact? Does it not give to the directors of this Company unheard of powers? I believe the most despotic minister that ever existed in any country never possessed such power as will be conferred upon the directors of the Electric Telegraph Company by this Bill, if permitted to pass. If the Committee is willing to hear the evidence which I am prepared to give, I shall be able to show that Mr. Bain has a still greater interest in opposing the bill than being merely a member of the public. It has been said by my learned friend, that as far as his legal position is concerned, it will not be at all affected by the passing of the Bill, and that he will have the same remedies at law then as he has now. Perhaps, technically, he will have the same remedies, but, I ask, is there no difference between a company possessing a capital of 600,000*l.*, with power to borrow what my friend calls the trifling sum of 200,000*l.* more;—is there no difference between opposing such a company and opposing the patentees, Messrs. Cooke and Wheatstone? Practically I do submit there is, and I am sure you will see that practically there is the greatest possible difference between them. Now, sir, it is the intention of my client, and he has already taken steps for that purpose, to litigate the validity of the most important of these patents. Those proceedings have been commenced—they have been commenced at the earliest possible period. They were commenced before it was known that this Bill was before Parliament. I ask you if you are not prepared to enter into that discussion which my friend professes to be so ready to meet, but which he throws every obstacle in the way of proceeding with—if you are not prepared to enter into that question; then, in the name of justice, I do ask that you will be pleased to adjourn the consideration of this Bill until after the proper tribunal shall have decided between my client and Messrs. Cooke and Wheatstone. I have no other observation to add. I leave the case with the greatest confidence in the hands of the Committee.

Mr. Hill—Sir; it appears to me the last observation of my learned friend, in effect, gives up his right to oppose altogether. He asks you to postpone the consideration of this Bill till some proceedings shall have terminated, the nature of which he has not specified—or in what court (if it is a proceeding at law) it is to come on. If it is a proceeding in equity, we are just as much in the

dark. Whether he means legal proceedings at all, or some other kind of proceeding we do not know. All I can say is, we have never been served, on the part of this gentleman, with any writ—with any subpœna to a bill in Chancery, or any one of those processes which are the commencement of actions or suits in equity; nor in his petition does he state anything of the kind. He says in the petition that some proceedings are about to be taken, but there he stops. What they are we don't know.

But supposing at this moment he had brought an action for piracy, I will say in the Court of Common Pleas, that in the Queen's Bench he was trying a *scire facias* to repeal these twelve patents, or that in the Court of Equity he was at the present moment proceeding for an injunction. Would this have any effect to stop these proceedings? No. Why not? Because that would have no effect on these proceedings at all. Those proceedings would go on, and the only effect would be this, that if he should turn out upon inquiry to have any good title, why, then, notwithstanding we have this Bill, we could not infringe upon his title. That is the only consequence, sir: it does not differ from this—the illustration I ventured to urge before you a quarter of an hour ago—suppose Mr. Cooke and Mr. Wheatstone were now to assign their patent to me at this moment in this room, have they not a right to do so? Certainly. How is Mr. Bain's position altered by their taking such a course? Not at all. Whatever they had a right to do I should have a right to do. Whatever they had no right to do I should have no right to do. They have no right to take Mr. Bain's patents and his inventions—I should have no right to do so. The law would be just as open before the assignment as afterwards. As far as Mr. Bain is concerned, what is this Act of Parliament? It is a Parliamentary assignment, doing nothing more than a private individual could do, except that it gets rid of the difficulty, that Mr. Cooke and Mr. Wheatstone, without the authority of Parliament, could only assign to twelve persons whereas they will now assign to the Company incorporated by Act of Parliament.

But, sir, my learned friend has taken a very original view of the case, supported by great talent, but quite original, and it is this. He says you permit landowners to oppose a railway bill, not because you are going to take away their land from them, but because there are a sufficient number of such persons to make an opposition, and if there were not, then you would look for opponents. Indeed! Is that so? Certainly not. The principle of admitting any opponent to be heard is, that you do not deal with him as one of the public, but you deal with him as having a peculiar interest; and I will illustrate that in a moment. Why, as to a class of the most important bills on which you are engaged you hear no opponents at all—a bill to create a capital felony? That affects us all in one sense. We may all get under the peril of the law, but you do not permit any one person to come before you and say, I will make a

speech and call evidence. I think it is a bill contrary to all policy of law and humanity; it will confer this power on that body, or that power on the other, and I think it unconstitutional. No; you, the representatives of the people, are intrusted with public interests; you are the counsel for the public; you have the same guardianship of all those interests which one man has as a member of the public only; and, therefore, it is that unless any person can show a private and peculiar interest which is about to be affected by this Bill, about to be cut down by this Bill, or about to be destroyed by this Bill, you say, "You must trust to us to guard the public."

They say here is a sort of despotism; a sort of ear of Dionysius about to be established; you will take care not to do any thing so wrong. That is for you to consider. If you think that great mischief will arise to the public, why then, of course, you will take care that it is not done; if, on the contrary, you are not afraid of any such matter, then, I think, you will find when you come to look at the Bill, care has been taken that this shall not be a private monopoly, but that the government shall have this power of obtaining intelligence from all parts of the country. This has nothing at all in common with my friend's fears, which proceed from his own vigorous imagination; you will find it is not only a most useful, but a magnificently useful plan.

Then my friend says, Oh! but if we have no public ground, we have a private and peculiar ground. Why, what is it? He says this Bill will put us into contention if we have to contend not with Messrs. Cooke and Wheatstone, but with a Company. Why! is it to be permitted that a gentleman shall come before the Legislature of this country and say the law is unequal, that the law is not the same for one man as for another, or the same for one man as for a plurality of men? Surely not. That gives him no ground at all. Why, I might object to any company being established on the same ground. I might object to a joint-stock bank being established on the same ground. I may have some dispute with them, and find them more difficult to deal with than a private individual. This goes to the root of companies being established at all, and therefore cannot be heard in any particular case.

Sir, I beg pardon for taking up time. When my friend said he had no ground at present, and that he hoped you would postpone the Bill till he had the ground, he did what I think is tantamount to giving up the case.

The CHAIRMAN—The gentlemen for whom you appear laid down the Telegraph from Slough to London?

Mr. HILL—Yes, sir.

The CHAIRMAN—What year was that in?

Mr. HILL—1839.

The CHAIRMAN—Have you ever had a notice of an action-at-law or any proceedings in equity?

Mr. HILL—None, sir.

Mr. BIRKBECK—Great alterations have been made in this Electrical Telegraph since it was laid down—great improvements. We are willing they should work the telegraph of 1837, but the telegraph which comes into conflict with us—the specification of this telegraph was not enrolled till last November. We did not know that they wanted to use such telegraph, I believe, till the month of January, so that no time has been lost. I am quite prepared to show that no time has been lost in litigating the question, and that every measure has been taken with the greatest diligence in order to bring it, if possible, before the Court of Chancery previously to the meeting of this Committee.

The CHAIRMAN—The question you submit to us is this. You ask us to postpone the Bill till the proceedings already commenced are settled.

Mr. BIRKBECK—We are quite willing to proceed before the Committee to show that the patents which you are asked to give permission to assign to a company are invalid; but if you do not feel disposed to enter into that investigation, then we ask you to postpone it for a short period, till we can have the matter decided by another tribunal.

Mr. HILL—The question before the Committee is, shall my friend be heard or not? not whether you shall dispose of the Bill. The question is, shall my friend be heard? Now when he says this, "I want to be heard to show we are about to institute proceedings," the nature of which he has not explained to us, "and you are to postpone this Bill until those proceedings are disposed of"—why, the motion to read the Bill this time six months is nothing to that; it is a motion to read the Bill this time ten years.

Mr. BIRKBECK—The summary proceeding is an application to the Court of Chancery for a special injunction.

Mr. HILL—My friend says a summary proceeding—that is a summary proceeding which you may have on any day which the Chancellor and the Vice-Chancellor are so open to hear that they will hear an application of that sort at an inn on the road-side when they are upon a journey. We are now in March, and they have not ventured to make such an application.

Mr. BIRKBECK—My friend knows, that before the Lord Chancellor will hear such an application, he requires that several affidavits should be brought before him, and those affidavits are not to be prepared in a day.

(Strangers were ordered to withdraw. The Committee deliberated, and strangers were again admitted.)

Mr. HAWES—What is the date of Mr. Bain's patent?

Mr. WEBSTER—He has several.

Mr. HAWES—Can you tell me the several dates? Give me the furthest case back, because that would include all others.

Mr. HINDMARSH—The first is on the 8th of January 1841, but that relates to electric clocks only.

CHAIRMAN—That would not apply.

Mr. WEBSTER—That will be found to apply; a clock is a signal. One person calls it one thing, another another, but they are the same things substantially. The fourth allegation is, "That on the 8th of January, 1841, your petitioner obtained a patent for an electrical clock, and the subsequent month he, in conjunction with Lieutenant Wright, R.N., applied for letters patent for an Electrical Printing Telegraph and other things.

CHAIRMAN—What is the length of your patent, that of 1841?

Mr. WEBSTER—Fourteen years.

Mr. HILL—That is the length of all patents; the first is always for fourteen years, neither more nor less.

CHAIRMAN—The Committee have taken your claim into consideration, Mr. Birkbeck, and the Committee are not willing to exclude you from being heard or taking any part, but they must confine you to this paragraph of the petition which I will now read: "That it will be an injury to the community at large to pass an Act which shall virtually exclude your petitioner from fair and honest competition in the art of constructing Electric Telegraphs."

Mr. HILL—Then we had better proceed with the proofs in the usual way, and when it comes to my friend's turn he will take such course to prove his case as occurs to him.

Mr. HAWES—The words in the petition, which give Mr. Birkbeck, as the Committee have determined, a *locus standi* here, and within which words he will have to confine his questions are, that Mr. Bain deems it to be an injury to the community at large to pass an Act which will virtually exclude your petitioner from fair and honest competition in the art of constructing Electric Telegraphs.

Mr. HILL—I am much obliged to the Committee for telling us what we have to proceed with.

Mr. Edward Cowper called; examined by Mr. Hindmarsh.

I believe you are a Lecturer on the Arts and Machinery at King's College? I am.

How long have you been there? Five or six years.

I believe you have been in the habit of lecturing both at King's College and also at the Royal Society for many years? Yes; all the institutions in London.

Have you inspected the inventions of Messrs. Cooke and Wheatstone with respect to the Electral Telegraph? Yes, I have.

Are you well acquainted with those inventions? Very well.

Will you have the goodness to describe to the Committee the mode in which the inventions operate for the purpose of communicating intelligence? I shall be able to give a general idea of the thing, and a very general idea, by calling your attention to the circumstance, that if an electric current is passed through a coil of wire, that coil of wire being surrounded by a piece of soft iron, that soft iron immediately becomes a magnet; and therefore, if we were to

take a piece of iron of the form of a horse-shoe, and take a coil of wire all round it, the instant communication is made with the battery the horse-shoe becomes a magnet, and the instant the communication is broken the magnet is unmade; and a piece of iron would be attracted and dropped by such a magnet. Then you see we have motion. By this being alternately raised and depressed it is quite capable of giving motion to a wheel, just the same as an escape-wheel to a watch; that is one form of motion. Another form is to take a magnet and merely pass a number of coils of wire like a large loop around it in this way, and on passing the electric current through that looped wire surrounding the needle, the moment the communication is made these needles are deflected. If you alter the current the other way, it is deflected the other way. So that the whole system of magnetic communication may be brought to this, making or unmaking a magnet, or deflecting a magnet. Both of those plans have been patented by Messrs. Cooke & Wheatstone, as I have been familiar with them for years past.

By Mr. Birkbeck.

Can you state which was the first invention of Messrs. Cooke and Wheatstone?

Mr. Hill objected to Counsel on behalf of Mr. Bain, the Petitioner, taking any part in the proceedings before the Committee, the petitioner having no *locus standi.*

Mr. Birkbeck was heard against the objection.

Mr. Hill was heard in reply.

Strangers were ordered to withdraw, and the Committee deliberated.

Strangers having been again admitted, the Chairman announced that the Committee had come to the determination not to exclude the Petitioner from being heard, but they should confine him to that paragraph in his Petition which stated that it would be an injury to the community at large to pass an Act which would virtually exclude the Petitioner from fair and honest competition in the art of constructing Electric Telegraphs.

Mr. Hindmarsh stated, that the first document he should put in evidence was the first Patent mentioned in the Bill of the 12th June, 7th William 4th. It had the usual clause, being a proviso against the assignment of the Patent to more than twelve persons.

Patents for England, of the following dates, were also put in :— 18th April, 1838 ; 21st January, 3rd Victoria ; 7th July, 5th Victoria; 8th September, 6th Victoria; 6th May, 8th Victoria.

Three Patents for Scotland, of the following dates, were then put in :—12th December, 1837 ; 21st August, 1840 ; 3rd July, 1845.

Three Patents for Ireland, of the following dates, were then put in:—23rd April, 1st Victoria; 27th October, 4th Victoria; 22nd October, 9th Victoria.

The specifications of the above Patents were also put in.

Mr. Cowper re-called; examination by Mr. Hindmarsh resumed.

(The shorthand-writer read the last answer given by the witness.)

That is the principle on which the Patent Invention had been brought forward; that applies chiefly, I believe, to the earlier Patents? To the earlier Patents.

Now, there was a somewhat different principle evolved in the subsequent inventions? A different principle evolved in the later inventions, inasmuch as the electricity is obtained from a magnet instead of from a battery; we agree as to electricity. In the first instance a battery is used and electricity produced from that battery is passed through a coil of wire round a piece of soft iron, which makes that into a magnet. The later invention differs from the first, not in the mode of giving the signals, because that you may deflect on the latter ones, or you may make it attract a piece of iron; but it is rather in the mode of producing electricity. In this latter plan, a large magnet is used by a coil of wire round a piece of soft iron, and being made to rotate, then this electricity is produced. Those pieces of wire carried away from that communicating the electricity so produced, may be employed in the manner that the electricity is which is produced from the battery. So that the electricity which is thus produced, may be used for deflecting a magnet at the end, or the termini, or for making as for unmaking a magnet, in the same way as the other.

In the later inventions, is there not also something different with respect to the mode of giving the signals instead of deflecting needles; is there not some other mode of giving the signals? The mode of giving the signals in the first instance was rather complicated. There was a series of five needles. Suppose five needles put into a sort of lozenge kind of form, and there are magnets to indicate letters. The first apparatus that I am acquainted with was a system of five deflecting magnets, or deflecting needles, as they are called; two of them pointing to a letter, which they intersected. So that, if we had this one (the witness illustrated his observations by showing the motion of the needles, &c., with two pens) standing so, this would be A, or if pointing here, it would be B, and so on with every other letter. There is a recent mode of indicating, by having merely two needles, that is one of those in use at the Great Western Railway; and those, instead of pointing by their interception, which limits their application, are made to indicate the letter by the number of blows given. If I might give a familiar sound, that (knocking the table once) would represent A; that (knocking twice) would represent B; that (knocking three times) would represent C: one, two, and three. So it is, that these needles pass on to the right in this manner:—one, A; one, two, B; one, two, three, C; and so on. And again, going off to the left in the same sort of way; and, in fact, the combinations of the needles are almost endless, and all telegraph systems may be considered as endless.

By the Committee.

Are you not liable to error in counting the number of blows from the rapidity with which they are given ? I should have expected it, but the practice proves the contrary. The telegraphist is very adroit indeed.

How are the needles made to give the blows ? They do not give blows, they merely deflect. There is no sound. I merely used the word "blows" to explain it better. A question was asked me as to the speed with which this is done, and I would just beg to mention a circumstance which I was witness to. I happened to be at Paddington on one of the great Derby days : at Slough somebody inquired the name of the winning horse. Somebody who had gone in and paid the shilling. The way the answer was given was this (explaining with his hand) R—u—n—n—i—n—g, then a cross (X), meaning the end of the word, then R—e—i—n, and then another cross.

(*Adjourned till to-morrow, at One o'Clock.*)

VENERIS, 20t DIE MARTII, 1846.

(CAPTAIN BOLDERO IN THE CHAIR.)

Major-General Charles William Pasley called ; examined by Mr. Hindmarsh.

I believe you are the Government Inspector of Railways ? I am.

Have you given attention to the subject of Electric Telegraph ? I have.

And other telegraphs ? Generally I paid very great attention to telegraphs, and to the Electric Telegraph lately.

Are you acquainted with the telegraphs which have been invented by Messrs. Cooke and Wheatstone ? I am.

These telegraphs I understand are now in use upon several railways throughout the country ? They are very extensively in use, and in my railway tours I find the number increasing. They are being extended almost every day.

As the Inspector of Railways, of course you have the means of ascertaining what is going on in that way in the erection of telegraphs. Now, in your opinion, what is the relative value of the old telegraph system of communication, and the Electric Telegraph system ? You mean the system of vision ? Yes.

The former system is very often liable to be interrupted by weather and the night. Telegraphs have been proposed, of which I believe one proposed by myself was the most efficient. These are also liable to be interrupted by weather and by fogs, and so on. The Electric Telegraph of Messrs. Cooke and Wheatstone can meet with no interruptions, and they are equally efficient by night and by day, and at all times of weather.

The old Semaphore that was in practice could not be used during the night at all? No, it could not. I proposed a night-telegraph which might have answered the same purpose.

That was never put in operation? It has been tried frequently, and approved especially by his late Majesty King William the Fourth, but they did not think it worth while to establish them; it was not deemed worth while to establish them.

And except during daylight, and then not when the weather is at all cloudy, the Semaphore could only, in fact, be used about a quarter of the twenty-four hours. Is not that so upon the average? I don't recollect the average. I have seen it stated in a paper in the supplement to the "Encyclopædia Britannica," on telegraphs, which I believe was written by Sir John Barrow, and I believe that interruptions were frequent, but the exact proportion I do not remember.

Now, have you seen Messrs. Cooke and Wheatstone's telegraphs in operation? I have, repeatedly.

And what is your opinion of that telegraph as an invention with respect to public utility? I am of opinion that it is of the greatest possible utility both for government purposes and to the railway system, as it may prevent accidents that otherwise might prove fatal.

You are of opinion that the means of communicating intelligence all along the line of a railway, would be of the greatest use for the purpose of preventing accidents? I am.

Then do you believe that whenever telegraphs shall have been erected along the lines of railways, it will be one means of insuring the safety of human life? Certainly. I don't say that it would prevent accidents, but it will prevent many.

Now, in addition to the telegraphs upon distinct lines of railway, do you conceive it would be of public utility to have all the railways connected together, or rather all the telegraphs upon railways connected together, so as to have a universal telegraph, as it were? I should think that in communicating from London to Aberdeen or Inverness, where, probably, there will be railways in operation, it would be important that the telegraphs on all these railways should communicate together, that they might be made from London to Aberdeen, or to Inverness, but I do not know whether it is necessary to make communication between the terminal stations of all the railways in the metropolis.

No; but for instance, to join the telegraph on the London and Birmingham, and that on the Grand Junction, to communicate with each other, to be one continuous telegraph, in fact? Undoubtedly that is what I meant, and also between the London and Birmingham, and the Midland Counties Railways, the Newcastle and Darlington.

And so on to the Edinburgh? Yes.

And would it not be much better that the communication should be made direct between London and Edinburgh, instead of going by successive steps from one place to another? I need hardly ask

you whether that would not be a very much superior mode of communication? It would be superior, but I don't know whether it has been carried into effect yet, if practicable, I should think it would be superior, but there is no difficulty in communicating by intervals, and there would be no loss of time, I should think.

There would be some loss of time, yet not much you think? Very little.

That would depend on whether the intermediate stations were near to each other or not, for instance, the station for Manchester might be at opposite ends of the town ; that would cause a very considerable interruption, would it not? If the line of railway is laid from one point to another, however distant, I should think the electric telegraph might communicate from one extreme end to the other, from the most southerly part of the kingdom to the other with very little difficulty and very little loss of time, but with respect to stoppages in such a place as Manchester, those, of course, would be avoided.

And has any other Electric Telegraph, except Cooke and Wheatstone's, been established in England, to your knowledge? Not that I am aware of.

I believe you are intimately acquainted with all the railways in the kingdom? I am.

Then I suppose it is hardly likely that a telegraph could be erected without your knowing it? A telegraph might be erected on a distant railway without my knowing it, because the railway companies do not make reports to the Board of Trade when they adopt the Electric Telegraph—they do not make official reports to the Board of Trade when they adopt the Electric Telegraph, and it is possible that some other telegraph than Messrs. Cooke and Wheatstone's may have been adopted in some part of the kingdom without my knowing it.

But you do not know of any? I have not seen any of a different form.

Do you remember seeing a trial of Messrs. Cooke and Wheatstone's telegraph on the South Western Railway some time in 1844? I saw Messrs. Bain and Wright's telegraph tried in the year 1844, and after that, Messrs. Bain and Lieutenant Wright, of the navy, proposed a telegraph to the Admiralty, which was tried on the South-Western Railway in 1844. The Admiralty requested me to compare it with Messrs. Cooke and Wheatstone's, and to report upon it, and I reported that Messrs. Cooke and Wheatstone's was much superior to the other—superior to Messrs. Bain and Wright's, or we may call it Mr. Bain's, for he was the inventor; and in consequence of my report, I ought to have said also in consequence of the opinion of Mr. Farraday, in favour of Messrs. Cooke and Wheatstone's, and also of Captain Brandeth, the engineer of the Admiralty, who was also required to make a report upon it, Messrs. Cooke and Wheatstone's telegraph—

Mr. Webster.

Were these opinions furnished to you by those gentlemen, or were they merely matters that passed between you? I conversed with those gentlemen on the subject, and I formed my own opinion from my own personal observation.

I shall be very glad to have your opinion.

Mr. Hindmarsh.

Had you the means of knowing whether they concurred with your own opinion? They did, I found afterwards. They concurred with me. We did not make a joint report signed by three, each made our several reports.

Committee.

But Mr. Farraday did make a report? I believe so.

Mr. Hindmarsh.

What was done after that report? What was the consequence of the report? In consequence of the opinion of Mr. Farraday, Captain Brandeth and myself seeing the great superiority of Messrs. Cooke and Wheatstone's telegraph for business, the Admiralty adopted Messrs. Cooke and Wheatstone's telegraph, which has been since acting on their line between London and Gosport.

That was erected, I believe, by the direction of the Lords of the Admiralty? I believe so.

For their use, and they are using it up to the present time, are they not? They are.

Now you stated the report you made to the Admiralty, do you still retain the same opinion with respect to those two separate telegraphs, Bain's and Cooke's? I do.

That the one is very far superior to the other? The telegraph established by Messrs. Cooke and Wheatstone long before my examination and comparison, was infinitely superior to what Mr. Bain's was then. It is very possible he may have improved it since.

But what that is you have no means of knowing? I don't think he could have improved it without borrowing some of the arrangements of Messrs. Cooke and Wheatstone.

What system of telegraphic communication did you see. Was it by deflecting needles? Do you mean Mr. Bain's?

Mr. Cooke and Wheatstone's. I saw two systems, one was by deflecting needles and the other was by electro-magnetism—a dial plate.

The two instruments next the table are deflecting aparatus? Yes, and the other a rotating instrument.

That is the dial-plate? Yes, by electro-magnetism.

And I believe the currents of electricity for the purpose of producing the action of needles on dials were conveyed along the wires suspended in the air? Yes, they were.

I believe the parts are so contrived that the wires are perfectly insulated from the earth? Yes.

Did you observe any difference between the rapidity with which signals were given by the one telegraph and the other? I did.

Which of them conveyed the signals with more rapidity? Messrs. Cooke and Wheatstone's conveyed the signals with much more rapidity, in the proportion of twenty to one.

Did you observe any failure in the communication? Did you observe that either of them failed to communicate signals correctly or properly? Yes, Mr. Bain's failed between the Nine Elms station of the South-Western Railway and Wimbledon, a distance of only six miles.

Were there many of these failures? When I saw Mr. Bain's first, he tried it in a room at a very short distance, and then it worked accurately enough. I saw it first at his house, and afterwards at the South-Western Railway terminus at Nine Elms; the distance being very short there, it worked very accurately, though slowly, as I observed, very slowly, with a degree of slowness that I should conceive inefficient for the purpose of telegraphic communication. Then he proposed to set up this telegraph between the station at Nine Elms and Wimbledon. We stated that unless he communicated between parts of some distance, that it was impossible to form an opinion. Well, he attempted to communicate between Nine Elms and Wimbledon. I went to inspect that on the 2nd of March, 1844. I found that his communication failed, inasmuch as he was obliged to use a very powerful voltaic battery, and without which it would not work, and his was a printing telegraph; the communication was so imperfect, that it printed one thing at Nine Elms and another at Wimbledon. Mr. Wheatstone also had prepared a printing telegraph, which I have seen working at short distances, which I consider much superior to Mr. Bain's, and it was capable of communicating intelligence three times as quick as Mr. Bain's.

Do you know the means of insulating adopted by Mr. Bain, by placing his wires in asphalt? Mr. Bain proposed at that time placing his wires in asphalt, but as that would involve a considerable expense, he adopted the system of placing them upon poles between Nine Elms and Wimbledon, the same system as had been adopted by Cooke and Wheatstone.

I dont know that I need do more than ask you to state in your judgment can there be any question with respect to the relative advantages to the public of the one invention and the other? Messrs. Cooke and Wheatstone's had been, for years before I saw them, in a perfectly efficient state, fit for every purpose of telegraphic communication; Mr. Bain's, when I saw it, was in an experimental state, and the first trial of it of six miles, between Nine Elms and Wimbledon, on a greater scale, failed entirely; it was in an entirely experimental state when I saw it first.

So far as you can speak of the two telegraphs, is there any comparison with respect to the public utility between the two? When I first saw Mr. Bain's, (I do not know what he may have done since,) but when I first saw Mr. Bain's, it was not in an efficient state at all; it was not fit for telegraphic communication.

And Messrs. Cooke and Wheatstone's was, you say, in a perfect and efficient state? Yes. I had at first, before I examined Mr. Bain's, had a very favourable opinion of it; there was a pamphlet published by Mr. Finlaison, which was put into my hands, in which Mr. Bain was described as having made important discoveries, which he charged Messrs. Cooke and Wheatstone with having appropriated to themselves. I also learnt, in conversations which I had had before, that Mr. Finlaison asserted that Mr. Bain was the inventor of certain discoveries, which afterwards, on perusing scientific works upon the subject, I found had been discovered long before he ever tried them in Hyde Park.

When was it that he made the trial in Hyde Park? I should think it must have been about the year 1842.

And you say it was known long before that? The principal discovery that he claims was made by Dr. Watson in 1748, as applied to common electricity, and it was afterwards applied to voltaic electricity repeatedly by others.

Long before 1842? Long before 1842.

Tell the Committee what that was? The principle was, that an electrical circle may be made by water, or by the earth, using only one single wire; that water or the earth were electrical conductors, and that one wire with one plate of zinc at the extremity of one wire buried in the ground, or immersed in water, and with another plate of copper placed in the ground or water at the other end of the wire, near the electrical machine and voltaic battery, will make a perfect circuit instead of using two wires, which had been considered necessary before.

Then the water, or the moist earth in that way operated in that case in the same way that another wire would? But not so efficiently. I have tried it.

It is not so rapid in its communication? In firing gunpowder at Spithead by the voltaic battery, I tried the water, in consequence, in fact, of having read Mr. Bain's experiments, for at that time I had not studied the history of electro-magnetism—so much so that afterwards I found that by one wire we could fire a charge at the bottom of Spithead, having a copper plate at one end near the charge and a zinc plate attached near the battery, but I afterwards gave that up entirely, the power was so much weaker where the two wires were used.

What would be the difference in point of time? The voltaic battery, in order to fire gunpowder, requires to have a certain power; if the power is deficient, instead of being instantaneous, which it ought to be, one is obliged to rub the wires, and sometimes rubbing

them for half a minute or so, an explosion may take place. I found that voltaic batteries of double the strength were required to fire gunpowder where only one wire was used, according to Mr. Bain's system, and therefore I gave it up.

Did it work with as much certainty if there was only one wire? I don't think it is so certain.

Nor so rapid? It would sometimes fail altogether; voltaic electricity ought to be instantaneous, but it would fail altogether with the same battery where the two wires were sure to succeed; and in earth I tried it by firing gunpowder in earth by two wires, and substituting the earth in the place of the second wire, and I found the effect of firing gunpowder in earth was very inferior, it required a battery of four times the strength.

That being the sort of thing claimed by Mr. Bain, I think you say you found the principle of that was discovered one hundred years ago? Yes; and in the Transactions of the Scientific Institution of Bavaria the same principle claimed by Mr. Bain had been tried by a Professor Steinheil. It was published in German, in the Transactions of that city in the next year, 1839, in a paper which I have read, and a Mr. Sturgeon, who at that time edited an electrical magazine, told me he had translated the paper of Professor Steinheil, the moment it appeared, into English.

In his own publication? In his own publication. I have a copy of my report to the Admiralty, made on the 10th of May, 1844.

Is that a copy of the report you made? It is.

Committee.

Perhaps you would like the permission of the Admiralty to hand that in? It explains my sentiments better than I can do now. I ought to have explained that on comparing the printing telegraphs of Mr. Wheatstone and of Mr. Bain, that Mr. Wheatstone's printing telegraph worked three times as quick as Mr. Bain's, and there was an assertion made by Mr. Finlaison and Mr. Bain that Mr. Wheatstone had appropriated his printing telegraph; that he had taken the idea from him, and Mr. Wheatstone's appeared to me so much superior, that I thought, if there was any copying in the case that Mr. Bain had copied from Mr. Wheatstone and not Mr. Wheatstone from Mr. Bain.

Cross-examined by Mr. Webster.

You have spoken of the impression on your mind; can you just give me the date of the particular circumstances that took place which led to this impression? On the 19th of February, 1844, I first saw, to the best of my recollection, Mr. Bain's telegraph at his own house.

You then first saw Mr. Bain's telegraph, and that was, as I understand you, a printing telegraph? It was; I saw it afterwards at the South-Western terminus.

That was a printing telegraph : in what way were the signals printed ? They were printed on a paper-cylinder that went round.

And that was on the 19th of February, 1844, and the first time you saw it ? Yes.

And that was at Mr. Bain's house ? Yes; I afterwards saw it on the South-Western Railway.

What was the number of wires employed in the printing telegraph at Mr. Bain's house ? The communication at Mr. Bain's house was made by a water-pipe at one end, and a piece of coke buried at the other ; the piece of coke and the water-pipe completed the circuit.

If I understand, you mean that the piece of coke and the water-pipe produced the current ? Yes; they completed the circuit.

Was it a complete metallic circuit then ? No.

You quite understand, that in these different sorts of inventions, in one case the metallic circuit was complete, and in the other there was no metallic circuit : Mr. Bain's was no metallic circuit ? No.

Was there a voltaic battery employed ? I don't recollect whether there was a voltaic battery employed; there was an electro-magnetic apparatus.

As that is a term that has been used before, and defined by Mr. Cowper yesterday, mention what we are to understand by an electro-magnetic apparatus as contra-distinguished from a voltaic battery ? It is an apparatus that magnetises iron, by means of the voltaic battery.

Then there was a voltaic battery, and by that means the electro-magnetism was produced ? Yes.

Now, I believe there is some little mistake, probably in terms, about that ; that is your impression at the present moment, but I should be glad if you would consider how, in that case, the electricity was produced, or whether you merely recollect it was a printing telegraph ? The circuit was produced through the earth by the water-pipes and the pieces of coke.

My question was, whether there was a voltaic battery or not, probably you do not remember ? I do not recollect the details of it.

Do you remember whether the circuit consisted of more than one wire ? It certainly did not consist of more than one wire.

It was a printing telegraph with one wire, and not a metallic circuit ? Yes.

Now with respect to the South-Western Railway, would that be described in the same terms; was that a printing telegraph? It was.

With one wire ? Yes.

And not a metallic circuit ? And not a metallic circuit.

And the wire was suspended in the air on posts ? Yes.

What was the kind of insulation adopted by Mr. Bain in that case ? It was by passing over wood and metal alternately.

Wood and metal pegs? I don't recollect whether they were wood and metal pegs, it was a common process.

There was one wire? Yes.

Did you give the date of this, with respect to the South-Western? The 2nd of March, 1844, was when I saw it, when it failed.

You do not remember any thing about the insulation on that occasion? By passing over wood and metal alternately; when it touched the metal the electro-magnetism was in action, and when it touched the wood it ceased.

Have you such a distinct recollection of it as to be able to say whether the insulation was complete, or anything like complete on that occasion, whether there was anything like insulation on the South-Western? I do not know exactly what you mean by insulation.

Whether such provision was made with respect to the pegs on which the wire was suspended on that occasion that insulation was obtained? I believe that there was, but I cannot say certainly, because I did not look into the details of it; and, in fact, I have not paid much attention to the machinery and detail of electro-magnetism. I know the general action of it, but I do not attempt to describe the electro-magnetic process.

You will excuse me for being particular, because you have spoken to facts that may be material? My belief is that it was insulated, but I cannot say, unless I had walked along the whole line.

Now, that also was a printing telegraph, and on the enlarged principle of what you had seen at Mr. Bain's house? Yes.

And one wire? And one wire.

Now, with respect to the telegraph of Messrs. Cooke and Wheatstone's, how many wires had that? The needle telegraph was worked by two wires, that is peculiarly Mr. Cooke's; the electro-magnetic telegraph of Mr. Wheatstone's was, I understood, worked by one wire only.

You understood the electro-magnetic telegraph of Mr. Wheatstone was worked by one wire only? Yes; that was what I understood.

I am speaking of the experiment on the South-Western Railway, were there two telegraphs? No; there were two telegraphs that had been tried before at the Paddington terminus of the Great Western Railway.

I understood you to have spoken before the Committee as to the comparison of experiments between the two telegraphs on the 2nd of March? On the 2nd of March there was no telegraph on the South-Western Railway at all, except Mr. Bain's experimental one; I was obliged to go to the Paddington terminus of the Great Western Railway, and I made the comparison there.

Now it was a telegraph on the Great Western Railway, and what was the date of that? I saw that at the same time, in the month of May, or previously to the month of May, 1844.

The experiment on the South-Western, of Mr. Bain's, was in March, you will remember. Yes.

Did you allow April to go over, or was it during April that you saw these experiments on the Great Western Railway? When I was requested by the Admiralty to give an opinion, I went immediately to compare both; I went to the Great Western, but I have no memorandum of the date.

You say it was before May? It might be before I saw Mr. Bain's experiment at Nine Elms, on the 2nd of March: it might be before it, or after it; it was about the same time; and I saw what had been established for years at the Great Western.

When you saw it, it was before May, at all events—that you are certain about? Yes.

Describe what was the sort of telegraph then in use at the Great Western. The needle telegraph was then in use, and it has been used generally ever since. The other telegraph was used occasionally,—the other telegraph was Mr. Wheatstone's electro-magnetic telegraph that was used occasionally.

But were these used at that time? Yes.

The one was the needle telegraph, which you say is the common one of Cooke and Wheatstone, and the other you call Wheatstone's electro-magnetic telegraph. Those are the proper terms to use, are they? I believe so.

What is the peculiar feature of the needle telegraph, as contra-distinguished from the electro-magnetic telegraph? The needle telegraph is acted on entirely by the voltaic battery, for which a very weak battery suffices.

But it was a metallic circuit? It was.

How many wires? There are a number of wires. The number of wires which act between the terminus of any railway and the far terminus may be two; but it is necessary to put intermediate wires in order to communicate with intermediate stations. Two wires are sufficient for the purpose of communication, except where there are more stations than one.

Between what stations did you communicate your experiments on that occasion? Between London and Slough. And then there were two wires?

There were more than two. There were several wires and several needles, I presume for the different stations; but the wires you experimented on were between London and Slough? Yes.

Have you a sufficient recollection to say whether there were but two wires and two needles then? There were only two wires in the dial-plate that I saw,—I saw them worked with only two.

Now you have described what you call the needle telegraph, will you just describe the peculiarity of the electro-magnetic telegraph of Mr. Wheatstone? In the electro-magnetic telegraph one letter or one sign of any sort, such as a number, is brought up to the top of a vertical dial-plate, which dial-plate communicates with a horizontal one, at which the operator sits, and turns round. Various

letters are marked on the horizontal dial-plate. The operator turns it round until he brings it to a point.

Opposite to a point which he wishes? Yes.

I do not wish to go into those particulars; all I wish to ask is,—how the electricity in that case is produced, and how many wires there were? I was told there was one wire.

You understood that? Yes; I understood there was one wire.

And that it was the metallic circuit? Not the metallic circuit all round; the earth operated partly.

Just describe, if you please, what you mean by the metallic circuit not all round and the earth operating partly. Yes; it is the same principle that was claimed by Mr. Bain.

So that, in that respect of its being one wire, and not a metallic circuit, but the earth operating partly, and its being electro-magnetic as you call it, Wheatstone's telegraph, which you then saw at the Great Western Railway, and Bain's that you saw at his house, and which you saw afterwards at the Great Western, were the same? On the same principle.

Was that what you call a printing telegraph:—we have got that the sources of the electricity were the same, but were the mechanical details, what you technically describe as a printing telegraph in Mr. Bain's the same? I do not think that telegraph printed, to the best of my recollection.

Then what would you call it? I called it the electro-magnetic telegraph.

Was it a needle? No:—no needle. I do not profess to explain the details of this machinery, but the Committee might easily see it.

You have given evidence; and everything of course that comes from you is of great importance, and it is necessary we should ascertain the fact. Now this was not a printing telegraph? To the best of my recollection it was not.

There is no doubt about that. When did you ever see or have shown you by Wheatstone a printing telegraph that you understood was his? I think I saw it at King's College, in one of the rooms there: he is one of the professors.

You were shown something by Mr. Wheatstone at King's College, and that was a printing telegraph? Yes.

Was that a metallic circuit? I do not recollect whether it was or not?

What was the date of that? I do not remember when I saw it. Whether I saw it before I instituted this inquiry, or afterward, I cannot recollect.

You can say whether it was before or after May, 1844? I rather think it must have been before.

You think it must have been before? Yes.

Was all the apparatus confined entirely within the walls of the laboratory? How do you mean within the laboratory?

Was it in King's College, or was it connected with any thing

across the river ? I think what I saw was not connected with any thing across the river.

You spoke of having read a pamphlet of Mr. Finlaison's ; is that the pamphlet you allude to (a pamphlet was handed to the witness)? I believe this to be the same—it is the same.

This is the book you said you had read ? Mr. Finlaison gave me a copy of it, and he distributed them very generally.

You have given the Committee some evidence respecting what you have learnt from the pamphlet; this is the pamphlet you refer to? Yes.

You have spoken of what was referred to you by the Admiralty. Was a letter of Mr. Bain's referred to you or not, do you remember ? I do not recollect.

Was it a joint report with Captain Brandreth ? No, I made my report separately.

You have alluded to some experiments with gunpowder. I believe that you found the circuit not metallic was insufficient—that it did not give sufficient intensity for firing gunpowder ? No. My impression after trying the thing is, that if Mr. Bain's telegraph in other respects was the best of the two, that it would be better to work with two wires than only one.

But you instituted some comparison which was founded on your experiments in firing gunpowder, which we perfectly well know, and you found that the circuit not metallic did not give sufficient intensity to fire gunpowder ? No, not with the same battery. It required double the quantity of battery in water; and, I should think, three or four times the power of battery in earth.

Did you institute any experiment that would enable you to compare the two, as regards the quantity of surface in each case ? How do you mean the quantity of surface ?

The quantity of surface that was required for the electricity in each case—the surface in contact with the water. In trying my experiment at Spithead we used large zinc and copper plates, and in firing gunpowder we made use of the tin case in which the charge was contained as one metal, and the other was zinc. It required a considerable surface of both metals to convey the electricity through the water.

Did you compare in those cases the surface of the plates in the cells with the surface of the plates you exposed to the water. Can you give the relative area of some of these surfaces? By referring to the records of these experiments, which were accurately kept, I could do so, but I cannot recollect them at present.

You cannot undertake to say whether they were equal, or what was the relation ? I should think the vessels containing the power were quite equal to the plates of the voltaic battery, but that the zinc plates laid down with the water near to the voltaic battery were not quite equal to the surface.

But the plates in the water were less in point of area than the

others ? They were both in the water. They must be both in the water.

You think the plates were the smaller of the two? I should not say. We sometimes tried large charges, and the iron or tin vessels in which the charge was contained acted as one plate, and from the wire near the voltaic battery other plates were let down into the water, which might have been less than the surface of the voltaic battery.

What were the number of cells which you employed? In firing gunpowder by the double metallic circuit we employed ten cells at 200 feet; when the water completed the circuit it reached twenty cells.

The plates in water being the same in both cases ? When it is a metallic circuit complete we require no plates in the water. We use none. The plates in the water are necessary to answer the purposes of the second metallic wire.

The Committee intimated their opinion that Mr. Webster was going beyond the latitude which they stated yesterday they would give him.

By Mr. Webster.

You spoke of a trial in Hyde Park; that was in 1842, you said ? I believe so, but I know nothing of it. I was not there. I heard of it afterwards. I wish, with the permission of the Committee, to make one remark, which is, that I consider the delay in Mr. Bain's telegraph was occasioned in a great measure by his using the printing apparatus. If it had been without the printing apparatus it would have been more simple, and I reported to the Admiralty that I deemed that part of it to be useless. I can see no advantage from having a printing apparatus, but much delay caused by it.

Excepting that, I do not understand you to say there was any difference in the rate in which the electricity was transmitted in the two cases, but that it was the delay of the recording signals ? Mr. Bain's apparatus was not perfect when I saw it. It was a failure, as I told you, when tried between Nine Elms and Wimbledon ; he may have made it more perfect since.

But it was the printing apparatus ? The printing apparatus caused delay, and I see no use in attaching a printing apparatus to an Electric Telegraph, none whatever.

Did you ever see it in operation without the printing apparatus? I do not recollect. Certainly not at Nine Elms.

Did Mr. Bain at any time show you any other telegraph which is called the I and V telegraph? I do not remember it.

Re-examined by Mr. Hindmarsh.

You say the earth was used as part of the circuit at the Great Western in the same way as Mr. Bain claims? I understood so.

And in the same manner that you have spoken of as having been discovered in 1748 ? Yes, by Dr. Watson.

Mr. Edward Cowper cross-examined by Mr. Webster.

You were asked a question by the Committee yesterday with reference to errors in counting the number of blows, whether that was liable to produce any error? Yes, an honourable member asked me a question, and I made, perhaps, rather an unfortunate illustration. I was showing how the diverging of the needle once, twice, or three times might give separate signals, and showed that by making sounds on the table.

Well, you have been lately at Edinburgh? I have.

You have been at Mr. Bain's establishment? I have.

He has a considerable establishment, has he not, for making clocks? Yes, in Hanover-street, Edinburgh.

Did you see the apparatus at that time? I did.

What do you call that—(handing a model to the witness)—is that the I and V mode of giving signals? Yes.

Does that illustrate what you spoke of yesterday about the mode in which the signals were given? Not precisely. Allow me to say that this model was made in consequence of my visiting Nine Elms at the invitation of Mr. Bain, and Mr. Finlaison, and Mr. Wright, and they showed me every thing that was there to be seen.

I was asking you a simple fact whether you had seen an apparatus like that at Edinburgh? You asked me was this the I and V model I described yesterday. It is not.

Is that a mode of giving the signals? That is a mode of giving the signals.

How are they given in that? By the electricity passing between the two cells—by a coil of wire placed at each end of a rod, the rod being supported by a slight spring, and resting on two frictions rollers, so that when the electricity has passed through the coil the rod diverges to the right or to the left—that is, to the I or to the V.

Now that differs from what you described yesterday as the needle telegraph, does it not? It differs in this respect—the needle telegraph turns upon a centre, so that if a needle were placed here—(pointing out the spot) it would immediately turn.

How many wires are used in that?—one needle, I suppose, and one wire? There is one needle here, one index, and one wire.

When did you first become acquainted with an instrument with one wire only? That I cannot say, because that I believe is the system that is now used generally to make the return current through the earth.

That is the system that is now used generally? I believe so.

Did you lecture upon that some time ago? I gave a lecture at the Royal Institution on signals and telegraphs in which it was natural to mention these things. I had made a note, "Mr. Bain, March 14, 1844," because he gave me every information I asked of him.

Now then, in March, 1844, you received information from Mr. Bains, and you lectured upon a telegraph of that kind? March 15, 1844.

How long before that had you become acquainted with telegraphs at all? As soon as they were brought out by Messrs. Cooke and Wheatstone. I had seen the telegraph at the Great Western, and Mr. Finlaison, jun., residing near where I do, and coming up in fact in the omnibus together, I was speaking of the telegraph. He said, "Have you seen Mr. Bain's?" I said "No." "Would you see it?" "Certainly. I will give fair play to all parties," and I then visited Nine Elms, where Mr. Bain's was, and he showed me this I and V telegraph worked in this manner.

It had one wire? That I cannot tell you.

However in March, 1844, an I and V telegraph was worked with one wire? It was not working, it was standing on the side, and Mr. Bain showed it to me. I thought it an ingenious thing.

There was only one needle? No, there was one index, there are two needles. I also saw the Printing Telegraph there at the same time.

How many needles were there used in the first telegraph of Messrs. Cooke and Wheatstone? Five.

And how many connecting wires? There was a wire I think to each.

Five needles and five wires? Yes.

Would there not be six with the return wire? There was one return wire, I believe, but I do not know the construction.

It was a metallic circuit, I suppose? I understood it so. I had not, at that time, heard of the return through the earth.

When did you first hear of the return through the earth applied to telegraphs to give signals? That I cannot tell you.

Was it before March, 1844? I cannot say.

Do you know that from time to time between the adoption of the telegraph with the five wires and five needles, and the state of things in March, 1844, of there being a continual reduction of the number of needles and the number of wires? Yes; because there were two just as you have them in Cooke and Wheatstone's.

And had there been an alteration as regards the metallic circuit being completed and not completed? My impression is, that that was done at the time, but you asked me the date, and I cannot say.

Did you see Mr. Bain's telegraph working on the Glasgow and Edinburgh Railway? I visited it the next day when I went down, and I visited it as one of the public.

How soon was your attention called, can you remember, in point of date, to the questions that arose and existed between Mr. Wheatstone and Mr. Bain? It was most forcibly called to my mind by a pamphlet that Mr. Finlaison presented me with.

Do you remember the date? It must have been about that time; they asked me to read it. I said, "No." He said, "Will you read it if I lend it to you?" I said, "Yes."

You have been an inventor yourself? Yes.

I think we owe the improved printing-press to you, do we not? Yes.

Had there been a prior patent for the printing-press? There had been one by Mr. Gunning.

Was that in the hands of a company? It was in the hands of Mr. Bensley, Mr. Richard Taylor, and Mr. Woodfall.

I believe you have had considerable experience in the difficulty of introducing inventions of all kinds? Well, I cannot plead guilty to that.

You know something of the difficulties of a poor inventor? I cannot say that; my first machine paid me my expenses.

I don't think that you occupied the position then that you do now? In what way?

You did not occupy the position in King's College that you do now? I have been invited there—I have not sought it.

I wish to ask you whether you, as an inventor, without any considerable funds, would have had any chance of competing with a company with unlimited funds, in the matter of rival inventions? There is no doubt that a company would have an advantage with funds, because funds are the sinews of commerce as well as the sinews of war.

You have had considerable experience in the litigation of patents. Do you know in what way it is proposed by Messrs. Cooke and Wheatstone, under this Bill, to carry out the patent? No, that I certainly do not.

Has your attention been directed to, or have you heard of a power which there is in the Bill for taking up the streets to lay down the invention in its present form? I beg pardon, I thought you meant any particular power in the telegraph. I should understand the power of the Company as being in the nature of the power of a Water Company or Gas Company.

Do you understand that. Do you consider that essential to the carrying out of the invention? Certainly, because they are stopped now, and it takes more time in coming from Nine Elms to the Admiralty than it does from Portsmouth to Nine Elms.

Then I may presume that it is essential, that the wires ought to be laid in the earth for the telegraph, and not to be carried on poles? They may carry it over the houses if necessary.

Perhaps you are not aware that there is a provision in the Bill that they are not to carry it over the streets? No; I thought it was probable they would carry it over the tops of the houses. The telegraph on the Great Western cannot be carried to Buckingham Palace.

The thirty-fourth section of the Bill is one which I wish to ask

you a question upon. The clause is, That it shall be lawful for the Company from time to time to lay down and place under (whether along or across, but not above) any street, highway, or other public way, lying in or across the line of any Electric Telegraph, or intended Electric Telegraph, any pipes or tubes which shall or may be necessary or convenient for the purposes of such telegraph," and so on. Now that power being in the hands of the Company, could Mr. Bain carry out his invention practically without a license from such a company? He could not take up the streets, no doubt, unless he were to have a company of his own.

And a Bill of his own? And a Bill of his own.

I need hardly ask you, as an inventor, whether it is easy to get up and find funds sufficient to form companies. I never tried.

Do you believe, if this Bill passes, with a power to the Company to take up streets and with the powers incident to that, that Mr. Bain can possibly carry on his trade of Electric Telegraphing? No.

Do you know any thing of the cost of laying down the telegraph? No; that has not come under my notice at all.

Do you know practically, from your own experience, the difficulties that subsequent patentees are liable to when prior patents are in the hands of rich companies? If I understand, your question means whether, in my opinion, Mr. Bain will be damnified or injured by this Bill. I should say not, and if you would allow me, I will give you an instance that occurred in my own invention. Mr. Beasley was a large capitalist, in fact, they had spent 13,000*l.* or 14,000*l.* When I had made my invention, I thought they had made so much money, that I offered them half the patent if they would agree to pay half the expenses, which was about 90*l.* The company refused it, but Mr. Beasley, as an individual, after the patent had run something like eight or nine years, gave us 2500*l.* for a third share of it. There was no difficulty. I have not sought, as a private individual, for capitalists in any way. I, as an individual, found no difficulty in fighting against a company. Then, on the other hand, there was a large company with something about 15,000*l.* or 20,000*l.* spent in the screw-propeller, and you are aware that in the case of an individual, brought before the court the other day, the verdict was in favour of the individual, namely, Mr. Simon, who was alleged not to have infringed the patent, and before a committee of the Privy Council, the other day, there was a 14,000*l.* company opposing the extension of Mr. Woodcroft's patent, and six years more was granted to him. I merely mention that as an illustration for the honour of the country. You think that there may be a prejudice. I admit there may be, but I put it upon this —I think Mr. Bain has some clever things ; there is a clock and so on, and if there was any occasion for me to go into that, and you were to ask me what his clock is, I should say that the clock which he showed me in Edinburgh is a very clever thing indeed.

Did you not see many things in Edinburgh in a very advanced

state, as regards the application of electricity; in fact, in a more advanced state than anything you had seen before? No, no; that is too general a great deal.

Did you not see many inventions by Mr. Bain very much more advanced, as regards the application of electricity, than any thing you have seen at Cooke and Wheatstone's? No; if you will ask me what I saw, I will tell you.

Just say yes or no, and then you can explain afterwards? I cannot say yes or no. I saw a clock worked by a battery from the earth, which I consider is entirely a new invention; I know of no person having any claim against that; I think it an extremely clever thing, and likely to come into general use. I am speaking of a clock worked by electricity entirely, and not a sympathetic clock.

By Mr. Hill.

A clock for time, and not for telegraphs? Yes.

By Mr. Webster.

Is that a matter contained in some of these patents of Cooke and Wheatstone? No; nothing at all.

Is there nothing in Cook and Wheatstone's patents relating to it? No; those are sympathetic clocks, one clock worked by another. Mr. Bain's has an original idea of working from the earth.

Did you see any cases of the application of the earth circuit, of the kind that you have described, with respect to clocks, to signals? The clocks I did, but not the signals; at Glasgow the telegraph is worked by a battery.

The application of electricity would be the same to signals as clocks, would it not? The telegraph at Glasgow is worked by a battery and with a return current through the earth.

Did you see that model worked? This was worked, not at the Edinburgh or the Glasgow telegraph, but in Mr. Bain's own office.

Can you say how quickly that worked? Yes, he showed me; that was much quicker in working than this (another model on the table).

Re-examined by Mr. Hill.

Is this claimed in any of the specifications before the Committee? No.

Do you know, Mr. Cowper, of any telegraph laid down by Mr. Bain in England? No, I do not; the experimental one at Nine Elms was afterwards, I believe, removed.

And you are very much acquainted with this subject of telegraphs? Yes.

Could any telegraph be laid down in England by Mr. Bain without its coming to your knowledge? That is saying too much; but I think I could, for Mr. Bain probably would have told me.

Mr. Bain has a telegraph from Edinburgh to Glasgow, in Scotland? Yes.

Have you examined that? I have.

How many of Messrs. Cooke and Wheatstone's inventions has Mr. Bain used there? I have not gone into the patents for that purpose. I did not consider this to be a question of the value of the patents, and, therefore, I merely went to a matter of fact.

Has he abandoned his own peculiar plan of asphalt and other matters in the telegraph from Edinburgh to Glasgow? Do you mean in insulating the wires?

Yes? The wires are there carried on the tops of posts.

He does not use his asphalt? No.

By Mr. Webster.

You spoke of the insulation: how were the wires carried on? Messrs. Cooke and Wheatstone's are insulated by little knobs, if I may so call them, as large as a walnut, with holes through them, and the wire passes through these holes, and they are fastened to the post, so that they are insulated by means of the earthenware. Mr. Bain informed me, he did not consider the earthenware so good, and he makes use of a small cap, like an inverted funnel, this is put over the top of the post.

What is it made of? A zinc cap, the insulation being produced by introducing asphalt between the posts and the cap; then the wire rests on the cap at the top.

Mr. William Henry Hatcher called; examined by Mr. Hindmarsh.

Are you the engineer of the proprietors of the patent? I am.

Are you engaged in laying down several telegraphs along lines of railway? Yes, I am.

The Eastern Counties? Yes.

Midland Counties? Yes.

Norfolk? Yes.

Great North of England? Yes.

York and Scarborough? Yes.

York and North Midland? Yes.

Hull and Selby? Yes.

Ely and Peterborough? That is about to be commenced.

South-Eastern? Yes.

Canterbury and Ramsgate? Yes.

South Devon? Yes.

I believe a distance of upwards of 800 miles? Yes, about that.

What is the expense of laying down a telegraph per mile? That varies from about 100*l.* to 150*l.* per mile.

I believe the cost of constructing these telegraphs will be somewhere about 100,000*l.*? Those that are at present in hand would be as much as that.

I believe you calculate, that altogether you will have about 5000 miles of telegraph to construct? I think that is a reasonable amount to assume.

Are you aware of the proposed plans of the proprietors to carry out the invention? Generally so.

Constructing telegraphs all along the lines? Yes.

To be used in connection with each other? Yes.

How do you connect the telegraphs with each other? That must be done by having proper offices for the purpose.

And with regard to the conducting wires, do you propose to take them under streets, by means of pipes? That appears to be inevitable in many instances.

You calculate there will be about one hundred offices required for this purpose? I think so.

The offices themselves would involve an expense, would they not, of about 100,000*l*? You may reasonably assume that.

Looking at all this great expenditure which must be necessary, do you think a capital of 600,000*l*. would be at all too large? I think not.

By the Committee.

You have spoken of 5000 miles that you think it probable may be applicable to Electric Telegraphs? Yes.

They are all along the lines of established railways? I think you may say as much as that on the lines of railways either now established or about to be established.

But Electric Telegraphs may be required in directions in which there are no railways? Certainly.

Do you know any instance of that sort? Several instances in which it might be very desirable, undoubtedly.

Therefore the 5000 miles is rather a low estimate of distance that may be covered by lines of Electric Telegraphs? Certainly so.

And it may be applicable, may it not, to either purpose, besides communicating between towns—it may be applied to a very great variety of comparatively domestic purposes? Yes.

Communications between large establishments? Yes.

Between town and town independently of a railway? Yes.

Therefore 5000 miles, I again repeat, is rather a low estimate, is it not? I consider it so.

Assuming 5000 miles to be the lowest estimate, and taking the mean cost of the lines to be 125*l*. a mile, how much would that amount to? I think 625,000*l*.

If you had to carry your telegraph through a populous town for one mile, have you estimated the expense of going through that mass of building? I have not estimated that expense but it would be more than carrying it along the line of a railway.

You mean more than 125*l*.? Yes.

You do not take that into consideration? I think you might take the mean as 125*l*.

Including towns and open country? Yes; it it is perhaps rather low even for that.

By Mr. Hill.

It is a low estimate? It is a low estimate.

By the Committee.

You have taken a low estimate of the cost, and of the probable mileage that may be covered with lines of Electric Telegraphs? Yes.

Would the lines underground require repairing? They might in case of accident arising from them. I know of no cause of natural decay.

When you say 625,000*l.* will be required, that is assuming they are all in progress at the same time? That is assuming they should all have to be defrayed out of that capital.

But if they are not all in formation at the same time you would not require the same capital? Not at once: it must eventually be required.

But that estimate you have given as the cost of laying down the lines? Yes.

There would be a great many other expenses previous to the laying down of lines? Yes; the providing of stores, which would of course amount to great expense.

And the whole establishment of a company? Yes.

Including salaries to officers, and so on? Yes.

Cross-examined by Mr. Webster.

Is this 600,000*l.* an estimate formed upon the lines that you have already laid the telegraph down upon? You may esteem those as data.

You have taken 100*l.* to 150*l.* a mile; what proportion of 600,000*l.* do you apply to laying down lines and what for offices? I think you may assume that as much as 100,000*l.* may be required for offices.

What is the object of those offices to be? To afford the means of communication from one place to the other to individuals who may require to avail themselves of the telegraph.

Do you contemplate connecting the various railway stations in London with each other? That might be done.

Is that part of your scheme? I believe it is so.

What have been the arrangements made with the companies in the lines you have laid down? In what respect?

Have they paid for them as you have gone on? They have paid for them.

Has there been any difficulty in laying the Electric Telegraph along the existing lines of railway—any difficulties of the Company? I don't know that there have been.

Any engineering difficulties? None but what could be overcome.

Do you know the Board of Trade has the power to compel many of them to lay down an Electric Telegraph? I have heard that is the case.

And do you calculate this Company is to lay down an Electric Telegraph along existing railways? That is what I understand.

Is it necessary for the purpose? It is necessary for the purpose to carry it out—to make it generally useful.

Along existing railways? Yes.

What single thing is there, as regards existing railways, which will not be done by the railways themselves throughout the kingdom, in the same way that has hitherto been done? Carrying it out to the extent that seems probable at the present time is impossible.

To what extent? To the extent of 2000 or 3000 miles.

I don't understand what you mean. So far as regards laying the telegraphs along the lines of railways, what use in the world is there for this Company? It is almost a general question.

A general question! Will you suggest any thing—one single thing—that this Company will do, so far as regards existing lines of railway, that Mr. Cooke cannot do and has not done? I think in many instances the Company might lay down lines on their own account, which might be a useful means of communication that it would be out of Mr. Cooke's power to do alone.

If the Company wanted a telegraph for any purpose whatever, along the line of railway, do you think they have any difficulty in doing it? If they had provided the necessary funds, I think there would be no difficulty in doing it.

How many miles of railway are supplied or being supplied with Electric Telegraphs? Being supplied about eight hundred miles.

Do you know that every railway may be compelled by the Board of Trade to put this telegraph down? I have heard that this is the case.

Now you have not pointed out to me any one advantage, or any one thing that this Company would be able to do, so far as regards existing lines of railway, that the railway companies cannot themselves do? I imagine the funds of an individual must be totally inadequate.

But I suppose railway companies have paid for this Electric Telegraph when it has been laid down? They have laid it down themselves.

Are the funds of the companies not adequate for that? When they lay it down themselves, I dare say their funds would be.

If a telegraph were wanted along a line of railway, or between any points on a railway, is it not quite within the funds of one or two individuals to lay it down? No, not unless they were individuals of great wealth.

You estimate it as from 100*l.* to 150*l.* a mile? Yes.

How are these pipes that are to be carried under roads to be insulated? The mode would be by carrying them by pipes of metal.

Do you contemplate any other mode of laying it down than by breaking up the streets? I am not aware of any other in towns.

Do you know of any practicable mode of laying it down generally throughout the country in the way you describe, excepting by breaking up the streets or the roads? Where it can be carried on poles and posts it might be so done.

What is the nature of the return that you expect on this 600,000*l.*? One of the most important would probably be that of the conveyance of important messages from town to town, or from one part of England to another.

You have estimated, you know, at from 100*l.* to 150*l.* a mile, and 5000 miles of it. What is to be the return on the cost? Probably the return would arise in a great degree, if not entirely, from the payment for the conveyance of messages.

Have you formed any estimate of that? No.

Have you any idea that you will get any return at all? I hope so.

You can give me no details of the estimate of any return at all? No.

Have any been made, do you know? I am not aware; they have not come within my notice. It does not come within my province to look at that.

Can you give me any detail of the cost of offices? I can give you no other detail than a general idea.

Re-examined by Mr. Hill.

You are aware there is a power in this Act by which government may call on the Company to lay down lines of telegraph—that will require a great outlay, will it not? Yes.

You are aware, perhaps, that on the South Western Railway a line of telegraph was laid down for the government, for which they pay 1500*l.* a year.? I have heard that is the case.

I was going to ask you, with regard to lines of telegraph laid along a railway. There must be certain wires for the use of the railway company, must there not? Yes.

And strictly for railway purposes? It will be desirable to have them so.

Now suppose you avail yourself of that telegraph for the general purposes of the country, you would put additional wires along the railway, and carry on those wires to an office at some distance from the railway? Yes.

And in that office you would have other wires which would go to the next railway? Yes.

And go all along the next railway, not interfering with the wires for railway purposes? Yes.

So that your own wires would connect office and office, whereas

the railway wires only connect terminus and terminus, or station and station? Yes.

Now in order to effect that object, would it be necessary to have a tolerably large capital, inasmuch as you could not draw upon the railways for these additional wires? Certainly.

To say nothing of the crossing of the offices? Yes.

Having considered well the subject, do you think a capital of 600,000*l.* unreasonable for such a vast object as this, which is contemplated by this Company? I should not think it unreasonable as far as I have considered it.

By Mr. Webster.

How many wires do you propose to use for this purpose in each case—five, or three, or two, or one? That would, in a great degree, depend on the kind of communications that you would require in any one instance.

But in the cases which you have laid down hitherto, how many have you used? We have used them in a great many instances.

The most recent? We have used one likewise in particular instances.

And that the more recent? Yes.

You originally used five, and now you have got to one? I was not connected with it when five were used.

You have gone on decreasing the number of wires, and now you have got to one? Yes.

By the Committee.

I suppose the capital required by this Bill would facilitate the erection of Electric Telegraphs—I mean not having to negotiate with companies, would have a tendency to spread its use? Yes.

I think you said there were 800 miles already concluded, or in progress of being concluded? Yes.

And taking that at 125*l.* a mile only, that alone is 100,000*l.*? Yes.

That is jointly advanced, I suppose, by individuals, and by the Company? Yes.

Have any difficulties arisen between the companies in advancing funds—any delays? I can hardly speak personally to it myself.

You do not know whether negotiations have been going on for some time? I am aware that in more instances than one negotiations have been going on for some time with companies.

And has the point of difficulty been the raising the necessary funds or not? I should think that was a likely point of difficulty, I don't know it myself.

Now if this central office in the metropolis should be connected with the different public offices, would not the laying down of such wires be very expensive in the metropolis? Undoubtedly.

And far beyond the 125*l.* a mile, which I assume is the mean cost? Very considerably beyond that.

Have you any profit arising out of the line you have laid down? Personally?

Now do you derive any profit besides that which you derive from laying down the lines? No.

By Mr. Hill.

Have the lines already down yielded a dividend? I believe so.

Are the lines at present the property of the companies? They are all.

But they have paid the patentee, have they not? They have paid the cost of erection, but they have not yielded any return as an annual return.

But they have paid a capital sum for the use of the patent? Yes.

By Mr. Webster.

The companies have paid so much a mile, and then you have erected the telegraph complete, and they use it? Yes.

It is their property, and they use it for ever afterwards? Yes.

By the Committee.

And being a beneficial use, they pay a capital sum for it? Yes.

By Mr. Hindmarsh.

The Great Western Telegraph is the joint property of the company and the patentees, is that not so? I cannot speak to that.

Mr. Hindmarsh.

Sir, we do not propose to go on with the evidence further, unless necessary, in reply to my friend's case.

The Chairman.

Then your case is closed.

Mr. Hindmarsh.

Yes, sir. As the case is now closed, it would become my duty to address a few observations to you upon the evidence that has been given, and to sum it up; but it is not my intention to inflict on you another speech; therefore I close my case here, and perhaps at the next meeting Mr. Webster will be prepared to go on with his.

(*Adjourned.*)

LUNÆ 23o DIE MARTII, 1846.

(CAPTAIN BOLDERO IN THE CHAIR.)

Mr. WEBSTER addressed the Committee on the behalf of the petitioner.

CHAIRMAN—Will you state to us what course you are going to follow?

Mr. WEBSTER—I shall address the Committee and then call evidence.

CHAIRMAN—On what point?

Mr. WEBSTER—On the general case.—Sir, it is my duty on behalf of Mr. Bain, to bring his case before you, and to state the public grounds on which he conceives this Bill ought not to pass into an Act, and the private grounds affecting him individually, and, sir, I feel some apology is due from me for not having stated more particularly the objections I intended to raise. But you are perfectly well aware that a party promoting a Bill, may put his opponent in difficulty by opening the case generally, and leaving the Committee in the dark as to the particular enactments, and the way in which they would affect private and public interests, and then getting his opponent called upon to state the specific grounds of his case.

That, sir, is my apology, and I hope the Committee will think, when I have laid the whole case before them, that it is one of a very different aspect from that which it at present bears. This case was opened to you as one very much of the ordinary kind, of the assignment of letters patent to a company. Sir, it differs materially from that as will appear from the comparison of this Bill and other Bills. Some difficulty, I think, may exist as to what it is the province of the Committee to inquire into. Opposition to Bills of this sort for the assignment of letters patent, have been very rare of late years. There was one, which I have before me, that was, I believe, opposed, and which led to the introduction of a special clause. They were more common a few years ago, when committees had to hear applications for extending the terms of patents, which jurisdiction is now referred to the Judicial Committee of the Privy Council, but so far as the public are concerned, the matter of inquiry is the same in every case, where the party comes for some alteration of restrictions to which he is subject, and therefore the rules which were adopted by Parliament before the jurisdiction of the Privy Council was established, and those which have been adopted by that body, are rules which the Committee will act upon; these rules are perfectly well understood, as laid down and reported in many cases before the Privy Council. The Committee of the Privy Council do not entertain questions of the sufficiency of the specifications, or of the novelty of the invention, but they do inquire into the general history of the invention to show what has been done to ascertain the merit of the

party and to see whether on private, as well as on public, grounds of utility, the extension of the patent ought to be granted.

Now, sir, these I conceive are questions before you, and I will observe that this is a peculiar case, namely, a privilege granted by letters patent. It is not an ordinary species of property which may be assigned in any manner. This being for the establishment of a trading company for working a monopoly which may lead to public inconvenience, the law has hemmed it in with every kind of difficulty. You cannot obtain a patent without being liable to opposition in every way. The Privy Council encourage opposition to applications for extensions, inasmuch as they will give costs to a successful opponent to encourage them to come for the protection of the public. And therefore, this is by no means an ordinary case. How did Mr. Hill deal with the case? I propose to address some observations to you following my learned friend, that I may not leave any ground untouched. He brought this case before you as if the application of electricity to telegraphic purposes was perfectly new in 1837; whereas the fact is, that it was the development of railways that rendered something of this sort necessary, which induced Messrs. Cooke and Wheatstone, and other persons, to turn their attention to the application of electricity to these purposes. It was perfectly well known long before 1837, that electricity might be used for the purpose of transmitting signals, but it was not till the Blackwall and other railways made it incumbent on the companies to adopt something of the sort, that the invention presented itself in its present shape. The invention appears to have gone on progressing; continual improvements have been made; the invention as now practised, differs widely from that originally laid down by Cooke and Wheatstone, and for all that appears before you at present Cooke and Wheatstone may have abandoned every thing patented. No witness has been called who could speak to the fact as to whether the invention, laid down in its improved form of one wire, was their invention, the last witness was utterly ignorant of it. No witness has been called to speak to the fact whether Messrs. Cooke and Wheatstone may not have abandoned every one of their inventions, and whether that which is now practised, and which Mr. Bain lays claim to, is not a different invention. Their existing patents may be utterly void, and may be mere useless monopolies. I do not mean to say that it is so, but it is a remarkable thing that the case should have been left so bare of evidence before you, and you will observe the importance of this when I come to address a few observations to you on what is the understood law with respect to useless monopolies.

Another remarkable omission on the part of my learned friend was, that he did not call your attention to any of the peculiar characteristics or provisions of the Bill. Now that is a most material thing for your consideration. The preamble of the Bill is, that it would be of public utility, that a Company should be formed with the power and provisions thereinafter contained. My learned friend said it only required a power similar to that possessed by every gas com-

pany and water company. Is there any gas company and water company that has power to break up every street and every road in the kingdom? It is the most extraordinary power that was ever heard of. And yet this is represented to be a Bill of course and in the usual form. I say, sir, this is a Bill entirely without precedent in many particulars. My learned friend said that some twenty Bills have been passed within the last few years, giving similar powers to companies. I hold in my hand some twelve or fourteen Acts for the assignment of letters patent, and this Bill differs from every one of them in a great many most material particulars, which may affect the public, and many of which will and must affect my client most materially.

Now, sir, what are those particulars? I will briefly enumerate them. First, it establishes a trading company with powers co-extensive with the United Kingdom, some of the letters patent not being so extensive, and not including the colonies. It empowers a trading company to hold lands; it empowers a company to buy thirteen existing patents, and to buy any other patents that have been, or shall be hereafter granted with reference to telegraphing by electricity. That is a most extraordinary power, a power far beyond any thing which is contained in any Act of this nature. It also empowers the Company to open any streets. It empowers railway companies to sell lands, it empowers railway companies to erect telegraphs, it affects existing Acts, existing railways, and existing rights, objections which would have been fatal on standing orders if the opponents of this measure had known of the existence of it, and then my friend treats all these extraordinary powers in this way; he calls them "a few other powers," and he says it is not right to arm a private individual with such powers. Why, sir, for all that appears before you, there is nobody connected in this concern, except Mr. Cooke and the honourable member, Mr. Ricardo. For all that appears this may be an application to grant a Bill to two persons with great powers, which they intend to put in practice in their own way and without any restriction; and another remarkable feature of this Bill is, that there are none of the usual clauses about general and other meetings.

Mr. HINDMARSH—They are all in the general Act.

Mr. HAWES—Is not that recited?

Mr. HINDMARSH—It is, sir.

Mr. HAWES—Just turn to it and read it.

Mr. WEBSTER—I thought it was confined to the land clauses.

Mr. HINDMARSH—It is the first.

Mr. WEBSTER—In that respect I was mistaken.

Mr. HAWES—It is in a very important respect.

Mr. WEBTSER—But it does not affect this objection. I say that for any thing that appears before you now there may not be more than two persons interested, and in that respect it differs from the Acts I have here before me. The important question on all Bills of this nature arises on this alienation clause, it is that, and that alone, that renders it necessary that an Act of Parliament should be ob-

tained. The letters patent were granted distinctly on the proviso that no more than twelve persons shall be interested in them. My learned friend Mr. Hill said, he hardly knew the object of that proviso, and he said it had formerly been altered by Sir John Campbell from five to twelve. I believe it was altered before that, at the time when Lord Denman was Attorney-General. If my learned friend had referred to the excellent work of Mr. Hindmarsh, he would have found the reason of the proviso. It was introduced in conformity with the spirit of the Act of the 5th & 6th George the First, commonly called the Bubble Act to prevent wild and ruinous speculations. I will read from the work of my learned friend Mr. Hindmarsh: "The object in restraining the alienation of these patent privileges has always been, firstly, to prevent the public being imposed upon by specious projects under the colour of letters patent, which too often terminate in the ruin of those who are induced to embark in them; and, secondly, to avoid the oppression which would be practised if large and powerful companies were permitted to become possessed of such privileges." That is perfectly well understood, and the law has adopted that proviso with the greatest jealousy in all cases. In almost all the acts passed by the legislature for extending the terms of letters patent, that proviso is inserted. I have referred to a great many; there are one or two that do not contain it, but the majority of them, in fact all, with the exception of one or two contain that clause. What might be the consequences of a patent being granted for an article for general utility without that proviso? I will put the case of an important patent invention which was before the Privy Council, the introduction of the manufacture of vegetable candles, by the application of cocoa-nut oil brought from Ceylon, and for the establishment of which trade the government had made considerable sacrifices. What might be the consequences of granting or extending such a patent for an article of very general or universal consumption without this clause? Some few persons engaged in that which has now become one of the staple trades of the kingdom, seeing the importance of the commodity, and the utility of it to the public, as affording a cheap and good candle, and to the colony as introducing a manufacture, which the government could not introduce, that its importance was pre-eminent, and that it would be one of the staple trades of this country, might create an odious monopoly in an article of universal consumption. If parties had the power of embarking an unlimited amount of capital without the regulations of an Act of Parliament, might it not lead to one of the most odious monopolies; and can you suppose that any candle-manufacturer has not a deep interest in opposing the extension of a patent of that sort? One or more candle-makers might be excluded from this trade, supposing a large number of candle-manufactures associated together in a town like London, for the exclusion of others. That is the very thing which this proviso was intended to obviate, and it is a remarkable thing, that in the only Act of Parliament which I have for the assignment of letters patent

relating to a trade of this nature, an Act of 1 & 2 Victoria, for the establishment of the Colonial Patent Sugar Company, which recites letters patent for England and Ireland in the usual form, there is this remarkable clause, that the company are not to practise the invention except in the colonies, but may grant licences anywhere. The reason of that is to prevent the consequences of an important manufacture, like the sugar manufacture, getting into the hands of a few persons. That clause was introduced to avoid the consequences of too extensive trading copartnership, and oppression by a number of persons in the particular trade combining together to raise prices and to keep out other persons. I say the introduction of a clause of that sort shows distinctly what is the object of the legislature, and when that is taken into consideration with the fact, that if a private Act of Parliament has been passed for extending or altering the terms, that no patent on the recommendation of the Privy Council is granted without these terms, that any body might oppose a patent to be granted without this clause before the Attorney-General, it is quite clear the reasons for this are reasons founded on public policy, and it is not a matter in the ordinary course that a power of this nature is to be granted.

Now, sir, in all these acts to which I have referred, the utility of the invention, and the advantage to the public, were the grounds on which they were granted. The case here differs in no respect from those, excepting that here you have not to inquire into the question of profit. The advantages and utility of the inventions are treated as conditions precedent to the granting of the Act, and the legislature has not granted the Act unless those are proved.

Before I leave this part of the case I would just refer again to the case of Soames's patent before the Privy Council, in which Lord Brougham said distinctly there were many cases in which the Privy Council would grant extensions which never would have been granted by Parliament—that the rules of the two Houses of Parliament are more strict in that respect than the rules of the Privy Council.

Then, sir, my friend says this has been submitted to the Board of Trade, and that the Board of Trade do not object to it. Are the functions of the House of Commons delegated to the Board of Trade? Suppose an application for letters patent to the Board of Trade under the 1st of Victoria, c. 73, an Act brought in I believe by Lord Sydenham, to allow the crown to grant certain powers by letters patent to persons associated together as a trading company, without incorporating them, notice must be given in the *Gazette*.

MR. HAWES—That had only reference to a limited liability.

MR. HINDMARSH—Powers to sue and be sued.

MR. WEBSTER—I do not say it had any thing to do specially with patents. I am using it only in this way. My learned friend, Mr. Hill, said this has been before the Board of Trade and they do not object, I say that is no answer.

MR. HAWES—But with regard to the case you cite it had only

reference to the right of suing and being sued; it had nothing to do with the incorporation of a company. It was a simple means of pointing out the mode of conferring a benefit on companies—it was never done except in one or two instances.

MR. WEBSTER—It has been found inoperative, but it was intended to give companies the benefit of certain privileges which it was thought would make it unnecessary for them to come to Parliament. I submit it is no answer to say that the Board of Trade don't object to this Bill or these clauses. We have had no opportunity of opposing them; but this matter must be of course taken into consideration on general grounds. Now my learned friend objected further, and I was very much pressed on this point by an honourable member of the Committee,—that our legal rights and position are not affected by this Bill. There is some ambiguity in the use of those terms. In one sense of the word we are not, in another sense we are affected. I say, first it is not true to say our legal rights and position are not affected, and if it were true it is no answer to our objections. My learned friend said all remedies were open to the petitioner, and he particularly specified the case of a *scire facias*. Suppose a person to bring a *scire facias* to repeal one of these patents after this Act is passed ; it may be a very grave question whether a *scire facias* would lie at all in that case, for the *scire facias* would be against the Company. But suppose this case: that the ground of avoiding the letters patent was the inconvenience of its being assigned to a great number of persons; if a patent is inconvenient it may be repealed on that ground, supposing that to be the ground of the inconvenience. Why, would it not be a distinct answer to say that Parliament had sanctioned such assignment ? The inconvenience is that there are more than twelve or a great number of persons interested in it. That ground of objection would be gone, therefore the legal right or remedy is affected in the strictest sense of the terms. But that is not all. Any party interested as assignee in a patent is a joint owner, a joint tenant, and such assignee may sue or grant licences. In the case of an assignment to twelve, any one of them may grant licences, or bring an action for infringement. Now is a person in no different situation when he has to contend with more than twelve, and when as many as 100 may sue him and grant licences ? I say it goes directly to the question of general inconvenience, and is a most material consideration. But that is not all. What is the position of Messrs. Cooke and Wheatstone and of Mr. Bain ? They are both parties having a *primâ facie* right, because it appears already in evidence, and will be proved, if it does not already appear, that Mr. Bain has patents—that since 1840 these parties have been rival patentees, and have been going on together. This therefore is a case of rival patentees. There are rival patents of a different date since 1840 ; some of Mr. Bain's are earlier than Messrs. Cooke and Wheatstone's. In that case the prior patentee has a right to have a

scire facias if he complains of an infringement. That right will be most materially affected by this patent being assigned, and all the patents being in the hands of a company.

There is one other case which I will put respecting this question of legal right, as it is a matter which has been much pressed upon me. We had a picture from my learned friend, Mr. Hill, about the eye of the Admiralty, and the Lords of the Admiralty seeing every thing that was going on in the Channel. What would be the consequence, supposing these patents pass into the hands of a company having an arrangement with government, and that an injunction was obtained by Mr. Bain against the Company? One of two things must happen; either the telegraph must stop, and the eye would be closed, or, under the proviso in all letters patent, that government might use the invention, in spite of the patentee; this Company would set Mr. Bain at defiance, by reason of the combination between a private trading company and the government. The latter would, in all probability, be the practical course; so that, this Company being established, an injunction would be inoperative. There are other cases in which Mr. Bain's legal rights may be equally affected; but that is not the question, whether they are, or are not.

This is not a tribunal to judge of legal rights. The question is, as to public necessity and public utility, and the interfering with private rights. We allege, on the part of Mr. Bain, that there are two parties having *primâ facie* equally legal rights, and that one of them will be precluded from the exercise of those rights, if this Bill passes. We say, it will be an injury to the community to pass this Act on the ground that the inventions of Mr. Bain, as compared with the inventions specified by Cooke and Wheatstone, are so superior, that all the telegraphs of Cooke and Wheatstone will be practically useless.

Now, Sir, that is a matter that you must look to in the same way as the Privy Council would look to it, and see what has been the progress of the invention and its present state; and it is remarkable that, in this case, there should have occurred, what has often occurred in other cases, that, at the time Cooke and Wheatstone's telegraphs are practically superseded by other inventions, an Act of Parliament should be applied for. I am not aware, with the exception of the Screw-Propeller Company, of any assignment of letters patent to a company having been of practical and public utility. It is convenient to get these Acts; but if a patent is valuable in itself as a good trading speculation, it has always been found that it has been kept in the hands of a few people, for reasons that are well understood; but if it begins to be useless, then is the time when large powers are sought for and obtained, and used to the prejudice of the public.

Now, sir, my learned friend having left the case in that way, as regards the general features of the Bill, states that it is necessary for railway purposes. No doubt; but will not the Railway Companies

get the benefit of Electric Telegraphs ? Where is the necessity of this Bill for railway purposes ? Then my learned friend talks about a central government office, and about a clause empowering government to lay down or use the telegraphs, and another object is the establishment of a central post-office. It may be, perhaps, useful to have a central post-office, but is not that a matter for the government ? Is that to be in the hands of a private company ? Is a scheme that is to affect the communications of all the parts of the world, and to be the eye of the Channel, as it was said, is that to be in the hands of a company ? This appears to me to be a scheme having no legitimate object, or that it is most material that the scheme should be in the hands of the government.

Next, sir, with respect to the evidence that my learned friend has brought forward. The witnesses he called were witnesses, remarkable, not for what they knew, but for what they did not know. His first witness was a gentleman of great eminence in his department, Major-General Pasley ; a person, who is applied to and who gives evidence in many cases, and whose evidence, of course, is very material. Now, what is the sum and substance of that gentleman's evidence. He first speaks about the telegraph having been laid down on railways, and he negatives at once one of the hypotheses of my learned friend ; namely, that the telegraph would be used as connecting the different stations in towns ; he says, that is not wanted ; he says, when railways are laid down, then the telegraph will be laid, and without any difficulty. But this gentleman is called for another purpose, and I must say, the General ought to have considered a little before he went so far as he did. He is called upon to give an opinion upon the comparative merits of two inventions, when it is quite clear he knows nothing about them. He asserts that Mr. Bain could not have improved his invention, without having borrowed some of the arrangements of Cooke and Wheatstone. What an extraordinary thing it is, that a gentleman of his eminence should come forward and make such statements, without knowing the least about the matter, without any fact upon which to found his statement! He is speaking of an invention of a totally different kind, and I could not help feeling, at the time, that I was trespassing on the patience of the Committee, in pursuing the cross-examination, but I knew how material it was. This gentleman is called on to condemn an invention, to institute a comparison between two inventions, and to say one must have been stolen from the other ; and what are the grounds for that opinion ? That in 1844 (and the date is material), that in February, 1844, and in March, 1844, he was called on to examine a telegraph that he saw at the house of Mr. Bain, and on the South-Western Railway. Messrs. Cooke and Wheatstone's patents, you will remember, date from 1837 to 1840—the first set of patents. The Blackwall Railway had been in full operation in 1840. In February, 1844, he pays a visit to Mr. Bain's house. He says, as regards what he

saw at Mr. Bain's house, the invention worked perfectly well, but that when it came to be applied on the South-Western, it failed. He says, Mr. Bain was obliged to use a voltaic battery, and that it failed. This will turn out to be altogether a mistake. When he was pressed, on cross-examination, it turned out that he did not remember perfectly the circumstances. He was speaking of a matter some time ago, and upon which he made a report. The General's evidence would have had very great weight with the Committee, unless sifted by cross-examination, and contradicted distinctly, as it will be. It turns out, that Mr. Bain's was a printing telegraph, and that Mr. Wheatstone's, with which he compared it, was an ordinary signal telegraph. I say, that gentleman ought not to have been called upon, without having a precise knowledge of the subject, to come and make use of his high position to give colour to the inventions of gentlemen, who unquestionably occupy a high position, and well deserve it; and Mr. Bain is not to be prejudiced, in this manner by a gentleman having a good feeling towards his rivals. Now, what further evidence does he give? He says, in the most unqualified terms, that Messrs. Cooke and Wheatstone's was in an efficient state in 1840, which I do not deny, but that Mr. Bain's, though it answered at his house, when tried between Nine Elms and Wimbledon, on a larger scale, failed entirely. Those are the words he used in his examination-in-chief. I asked him, if he knew anything about the insulation. No, he did not; and yet this was the gentleman who was sent down by the Admiralty to report upon the telegraph. I do not make any complaint of his being sent down, or of his report. I have no doubt he made an excellent report, and that the report will speak for itself; but what was he sent down to examine? The printing telegraph of Mr. Bain, not the qualities of a signal telegraph. You will find that the wires of this telegraph of Mr. Bain's were put up on posts, and not perfectly insulated. It was a mere experiment to show the merits of the printing telegraph, and had nothing to do with the telegraph as a signal telegraph. With respect to the opinion of the General, that Mr. Bain's experiment, in 1844, was a failure, it will turn out that he is mistaken, and that he had forgotten the circumstances—that he was comparing two totally distinct instruments. When his attention was called to this, it rather startled him, and he said, "I must mention, the only objection to it was, that it worked slowly."

Mr. HINDMARSH—He did not say the only objection.

Mr. WEBSTER—You will hear from Mr. Bain and Mr. Cooper what the fact was, and you will find this gentleman was entirely mistaken; but be his evidence of much value, or of little value, it was not right that he should have been allowed to come and give it in this manner. If his evidence had not been cross-examined and sifted, it would have gone forth to the world as condemning an invention of Mr. Bain's, which will turn out to be a most important invention.

Then, sir, after having discussed this matter, of the comparative merits of the inventions, he goes on to speak of a pamphlet he received from Mr. Finlaison, and that he found Mr. Bain laid claim to things not his invention, and which were old. It turned out afterwards, that he had not paid much attention to electro-magnetism, and yet he took upon himself to condemn Mr. Bain as having laid claim to what had been discovered by Dr. Watson, in 1748. Now, the General was speaking of something that was not known till 1800, when Galvani discovered the properties of voltaic electricity and the action of metals. So that this gentleman comes forward and confounds two discoveries together; the fact being, as will appear from the evidence of Mr. Cooper, that Dr. Watson discovered, in 1748, that the earth is a conductor of frictional electricity; that Galvani discovered general voltaic electricity, in 1800; that Steinheil discovered the earth was a conductor of voltaic electricity, and that Mr. Bain discovered that the earth was a generator of, as well as a conductor of, electricity. The General has confounded the one thing with the other, from the beginning to the end, and has come forward and condemned Mr. Bain's invention, and charged him with a piracy of Cooke and Wheatstone's inventions.

Mr. HINDMARSH—I must interrupt my friend, for he is mistaking General Pasley's evidence which was not respecting the generation of electricity, but only the conducting; my friend is mistaken in all his observations.

Mr. WEBSTER—Sir, I say it was not right for General Pasley, considering his eminence, or right for my learned friend to bring him here to speak of Mr. Bain as he did; and to say, that "Mr. Finlaison asserted that Mr. Bain was the inventor of certain discoveries, which afterwards, on perusing scientific works on the subject, I found had been discovered long before he tried them in Hyde Park." The General then goes on to speak of Dr. Watson's discovery, in 1748; of other experiments, published by the Bavarian Institute many years ago; of a paper from Steinheil, published by Sturgeon. The simple fact is, that the course of inventions was, as I have told the Committee. Dr. Watson, in 1748, discovered one thing; Steinheil discovered, and Sturgeon published, in this country, another; and Mr. Bain, at a period subsequent to the first patents of Wheatstone, discovered the earth to be a generator as well as conductor of electricity. I am sorry to say, that is not all; the General said, that Mr. Bain had complained of Mr. Wheatstone having stolen something from him, whereas he believed, if there had been any stealing, that Mr. Bain had stolen from Professor Wheatstone. You will hear what the facts of the case are; and, when Mr. Bain is thus disparaged, it is a matter of importance to consider, whether the promoters of this Bill ought to have the great powers they ask at your hands.

What, sir, are the facts? Cooke and Wheatstone's first patent was in 1837, the second was in 1838, and the third in 1840.

With the year 1840 began another era in the invention, of a remarkable character. In considering the merits of the case, and, whether the public interest will or will not be sacrificed by this Bill, you will have to consider this era of invention. Mr. Bain, originally apprenticed to a watchmaker in Scotland, came to London, about 1837 or 1838, to pursue his trade. On attending lectures in this city, at which the powers of electricity were explained, he was at once struck with the notion that it might be applied to the purpose of indicating time and signals; and, from his experience as a practical man, seeing what use might be made of it, in August, 1840, having made the discovery of the electric clock and the printing telegraph, about which you have heard something, but being without funds or patronage to introduce it, applied to Sir Peter Laurie, who gave him a letter of introduction to Dr. Birkbeck, who was too ill, at that time, to be seen. He then called on Mr. Baddeley, who recommended him to call on Professor Wheatstone. He called on that gentleman on the 1st of August, 1840 (Messrs. Cooke and Wheatstone having specified in June or July, of the year 1840, the last of the first series of patents, to which I called your attention), and says to him, "I have invented an electric clock and printing telegraph." The professor said nothing about any invention of his own, or of the specification which had just been enrolled, but advised him not to trouble himself about the electric clock, and entered into an agreement with him to make a model of the printing telegraph.

An agreement was entered into upon which I believe he received 5*l.* He was in considerable want of funds, and he saw the Professor again on the 18th, and then some further agreement was made, and he was to receive 125*l.* upon certain models being completed. He did all he could to perfect these, and brought them to the Professor. The Professor received some of these models, but Mr. Bain never received the money. Now, from that time to the present these gentlemen have been in collision; and you will see, when I call your attention shortly to the progress of the inventions from that time forward, where the merit lies, and what is the state, as regards the public, of the invention of Cooke and Wheatstone in 1840, and of the invention of Mr. Bain at the present time. My learned friends knew these facts, and they have had notice to produce the documents: these facts having been matter of controversy in the public journals, it was rather extraordinary that the General should have been allowed to come and give such evidence condemning Mr. Bain, and saying, if there had been piracy, it had been the piracy of Mr. Bain from Professor Wheatstone, and not of Professor Wheatstone from Mr. Bain.

Before I quit this part of the subject, I wish to observe that there are one or two things proved by the General which are most material. It is proved that in March, 1844, Mr. Bain had an electro-magnetic printing telegraph. It appears also that the Professor about

the same time had something of the same kind, but betwixt August, 1840, and this date in May, 1844, we know nothing. You will see what did take place when Mr. Bain is called and all the circumstances are laid before you.

The CHAIRMAN—This is all a question of piracy, is it not?

Mr. WEBSTER—No, sir, it is exactly the matter which the Privy Council would inquire into.

Mr. HAWES—Precisely; but we are not the Privy Council.

Mr. WEBSTER—You are exercising functions of the same sort.

Mr. HAWES—No, no.

Mr. WEBSTER—If it should appear most distinctly that the present state of the invention was Mr. Bain's and not Mr. Wheatstone's, and that Mr. Bain's invention was ten times more valuable, and could be worked so much cheaper, commercially, that the public would adopt the one and not the other,—

Mr. HAWES—Then this Bill is not worth a farthing.

Mr. WEBSTER—We have a strong opinion on that, and I trust that in the discharge of my duty I shall not travel out of the limits which the Committee has assigned to me. I shall show how the public will be affected by it, and how our private interests will be affected; but I do submit with great confidence that when you are asked by a party for a measure of this sort, when there are well-established rules adopted by the Privy Council (because it may not have been customary for honourable Members to hear cases of this sort) that you will not shut your eyes to the course of practice formerly pursued before this tribunal and others. The Privy Council do not inquire into portions of piracy, or novelty, or questions as to the sufficiency of a specification, but if the patent is clearly void, if the progress of invention is such that the party opposing the patent has contributed to the public good as much as the other has, then they say there is no merit in the party applying and that he is not entitled to that for which he asks. That is going to the question of public utility.

Now, sir, what more is proved in this matter, which brings us at once to the position of Mr. Bain? It is proved by Professor Cowper that in January, 1844, he lectured upon information which he received from Mr. Bain upon a signal telegraph of one wire and one signal plate, by means of a circuit, not metallic, and that appears distinctly on the evidence to be the state of the invention as now adopted by Messrs. Cooke and Wheatstone themselves. Now then, when it appears on the case before you that the invention in respect of which they ask the extraordinary power is one that, *prima facie*, has been borrowed from Mr. Bain, that the merit is due to him, it is surely material, in considering the merit, to inquire and look at what are the simple state of facts. You are not to pass this Bill, which is to confer a great benefit upon these parties, and to repeal clauses inserted in every patent and in every Act of Parliament, without

inquiring how the public will be affected by it. It is on that ground, and that ground alone, that I put it—it is one of public right.

Now, sir, as regards the question of private injury to Mr. Bain. What does Mr. Cowper say on that? Mr. Cowper cites the case of the printing-press. I knew how well that bore on the present case, and consequently I put the questions to him. What was that case? Parties having a prior patent refused to enter into an arrangement with him, and he says—"I was not injured, because one of the parties afterwards entered into an arrangement with me." We say we shall not be injured if we can enter into an arrangement with one of these gentlemen; but if we do not, can any man doubt, commercially speaking, Mr. Bain will be practically excluded from his trade. What use will be made of this power of breaking up the streets, and of other powers to which I have called your attention, as against a party not having those powers? What will be the immediate operation of this Bill? They will enter into arrangements with every railway, and they will exclude Mr. Bain, of necessity, by the operation of this Bill, from every railway; they will exclude him from every street, because he has not the power of breaking them up. The honourable Member for Lambeth suggested that Mr. Bain might himself come for a Bill. Is it to be supposed that Parliament will give several bills of this description?

Mr. Hawes—Why not? Parliament has given Bills to water companies, and several gas companies.

Mr. Webster—Other companies have a limited jurisdiction. If my learned friend's Bill had been confined to breaking-up the roads between the Admiralty and Nine Elms it was perfectly competent to Parliament to grant that power, and there is no objection to it; but if it sanctions a measure of this sort, giving powers co-extensive with the United Kingdom,—if it sanctions two Bills of this sort, why not twenty? Where is the necessity of Mr. Bain applying for a Bill when there are two courses open to you, either to give Mr. Bain the power of obtaining the same benefit by this Bill, or to reject the Bill altogether on public grounds.

Mr. Hawes—That is a matter for you below the bar. We have nothing to do with that.

Mr. Hill—It will require a good deal of consideration.

Mr. Webster—Every thing has been done on our part that could be done. We say we shall be completely destroyed.

Mr. Hawes—Are you arguing against the public policy of a Bill which you ask the Committee to consider whether it might be right for Mr. Bain to participate in? I think that is a fatal argument.

Mr. Webster—It is in answer to the question from the honourable Member, why should not Mr. Bain come for a Bill? I say we are irretrievably ruined, and you will hear the reason of that from gentlemen of experience who know the operation of extensive trading monopolies. Gentlemen unacquainted with mercantile transac-

tions may know nothing of these inconveniencies, but persons connected with trade and commerce know what is their operation. Why do people come for Bills for companies of this sort, but for the sake of the benefits obtained and the influence which large capital gives them. It is unnecessary, I am sure, for me to tell the Committee that commercial men know, and people interested in patents know, how injuriously Mr. Bain's interest will be affected by this Bill. Mr. Cowper instanced the case of a private individual and a company in answer to a question which I put to him. He instanced a case before the Privy Council, where a company was opposing Mr. Woodcroft in obtaining an extension of a patent. What did the Privy Council do in that case? They protected the individual against a company—the very thing which I trust we shall receive at your hands.

Mr. HAWES—So will the Privy Council protect you against the Company.

Mr. WEBSTER—That was the case of the screw-propeller, and that is the only case that I am aware of in which an act of this sort has contributed to the public benefit. And how did that contribute to the public benefit? Why, in a way that this cannot. In that act, and in most of those other acts which I have before me, it is recited that certain persons, being convinced of the utility of the measure, but being satisfied that private funds could not effect the object, it was necessary that a company should be formed.

Mr. HAWES—What are you referring to?

Mr. WEBSTER—The Ship-propeller Company's Act. That, sir, is the solitary instance of an Act of this sort, so far as I am aware, having been of service to the public. Here was an invention for applying the screw for the propelling of ships. We know how important that has now become—so important, that many of our ships of war are to be fitted with screws. This act recites that certain persons were satisfied of the utility of the invention. It was impossible for an individual alone to build ships. I believe that company spent 40,000*l.* in proving to the public the utility of the invention. This was a case of necessity on the part of the public. It was necessary to prove the utility of an invention as to the utility of which a few persons, reasoning on scientific principles, were well satisfied: here was a proper case for an act of this sort. But where is the case for an act where the utility is already established, and where ordinary persons can carry it out, unless powers are wanted for purposes not perfectly straightforward, so far as regards trading, with reference to the interests of other persons?

Now, sir, that being the effect of Mr. Cowper's evidence, and the way in which it bears on the case, the last and only witness is their own engineer—a gentleman who knew nothing about the invention till within the last two or three years. What does he tell you? Why, that the average cost of constructing the telegraph is 125*l.* a mile. I will show you that Mr. Bain has laid down on the Glasgow

and Edinburgh railway a telegraph, infinitely better than Messrs. Cooke and Wheatstone's, at 50*l.* a mile, and with profit to himself; and that, being paid mile by mile, he would take any number of miles on those terms, being paid as he went on at 50*l.* a mile. Now if that be the fact, (and there will be no doubt about it), and if the fact be that the inventions in their present perfect state, are the inventions of Mr. Bain, and of no one else, and if his telegraph can be laid down at half the expense, perhaps much less, about one-third, of the cost of the estimate upon which this Bill is founded, where is the necessity for a bill of this sort? What use is to be made of it except to oppress Mr. Bain? We believe that commercially we shall be ruined; although, with regard to cost, which is a fact on which you must consider the question of utility or no utility, it appears that a better rival invention can be laid down at a cost that is certainly half, and perhaps one-third the estimate of the Company. So far as regards the question of railways, the railway companies have already adopted it; and is there any railway company in the kingdom that would not gladly lay down an Electric Telegraph for the Government at five per cent. on the outlay? Cannot the railway do it cheaper than any body else? Therefore, so far as regards laying down the telegraph along railways, there is no case for exclusive privileges. But it was suggested by an honourable member that they might want to lay the telegraph down where there were no railways. The promoters of the Bill did not dare put their case on that, and for this reason;—they knew it would fail them as regards estimate. The estimate brought before you relates to telegraphs on railways.

They further tell you they want this money for offices, for taking lands where there is no compulsory power, for the furniture, &c., of offices, and a variety of matters of that sort, to which their estimate is totally inapplicable. Did Parliament ever do any thing so wild as to grant a Bill for raising a capital of 600,000*l.*, with power to borrow 200,000*l.* more, there not being a shadow of estimate as to any return, or any definite and well-defined purpose to which the funds of the Company are to be applied, and the object from which the estimate is derived, namely, the laying the telegraph down on railways, being an object for which such capital is wholly unnecessary. I say that for the first time, if this Bill passes in its present form, will Parliament have sanctioned a measure of this kind? In the ordinary case of a Bill with respect to public works, it is necessary to show some detailed plan, some grounds for believing it would be commercially useful, but that has not been done in the present case.

It must appear to the Committee, as a condition for sanctioning a Bill of this sort, that the capital is a proper and reasonable capital, and that the returns will be such as may, on reasonable expectation, be commercially advantageous. You have not a tittle of evidence before you that can lead you to come to any such conclusion. The

evidence is drawn from such a state of things that the objects of the Bill are wholly inapplicable to it. Now to what item does the average of 125*l.* a mile relate? It is for posts, wires, and the telegraph, the railway company finding every thing else. Can an estimate for materials of that sort, founded on such a basis, be of any use in showing to you what is the proper capital for establishing offices and buying land without compulsory powers. The capital of 600,000*l.* may be too much, or it may not be enough. For all that appears before you, 10,000*l.* may be enough, or a million or two millions may not be at all adequate.

Now I have already called your attention, sir, to what is a peculiar feature in this Bill, namely, that for all that appears there are no parties but these two gentlemen interested in the measure. Parliament does not give powers of this sort without knowing something more about the Company. These two gentlemen may be getting their present powers, intending to work the invention themselves. My learned friend called it a magnificently useful plan. So it may be in some respects; but I say there is no such case made out before you, there is no detailed plan shown; and the estimates that have been laid before you are entirely without any evidence of a prospect of any return, and for all that appears to you, the Bill may be entirely abortive, excepting so far as it will give powers that may be used for the purpose of oppression.

I submit, therefore, sir, with reference to the two principal grounds, that the Bill is prejudicial to the community; that for all that appears on the evidence, the invention of Cooke and Wheatstone may be superseded by the invention of Mr. Bain; and that in a commercial point of view, the former would never be adopted except for the factitious support given to it by this Bill.

Now, sir, what is the well-established rule as regards patents for useless inventions? Why will Parliament, why will the Privy Council, why will courts of law give no encouragement to patents that are practically useless. Because they are creating a monopoly, which stops improvement. And therefore when it appears, as it does in the present instance, that the earlier patents have been abandoned—

Mr. Hindmarsh—It does not appear yet.

Mr. Webster—The evidence is distinct on this point, that at first they had five wires with a complete metallic circuit, whereas they have now got to one wire, and abandoned the metallic circuit, and there are other details with which it is unnecessary to occupy your time. That being the case, is it not fair to presume that the earlier patents are practically useless. I say practically, because the test is, can they be worked practically, having regard to the present state of invention? When I say an invention is useless to the community, that is what courts of law, the Privy Council, and Parliament always understand, having regard to the then state of invention, as making the invention specified practically useless. For

all then that appears in this case, the earlier patents of Cooke and Wheatstone may be useless, and the presumption is, that the invention that is now useful, is Mr. Bain's. Without entering upon any question of piracy, for all that appears before you, their invention may be a useless invention, as compared to that which is now in use, and the promoters of the Bill ought not to have left the case in this way. They knew perfectly well the course which this case would take. If it had not been the tenderest point in the world, they would not have put Mr. Cowper forward, and then immediately withdrawn him.

CHAIRMAN—It was requisite that they should do so to raise the point as to your right to be heard.

Mr. WEBSTER—Yes, sir, but they did not offer any evidence of the kind I am now adverting to.

Mr. HILL—I beg pardon; I have heard a great many statements that have no foundation, but I do beg to call the attention of the Committee to this, that I offered to go step by step through the whole of this invention, for the purpose of showing priority in every step from beginning to end; that I am prepared to do now, if the Committee are prepared themselves to depart from their own decision, and try the question of piracy or not. Personally, those gentlemen would be delighted that the Committee should so depart, and let them in to prove what they undertake to do, the utter falsity of all these statements my friend is instructed to make.

Mr. WEBSTER—I say it is not trying a question of piracy, and not a departure from the rule which the Committee have laid down. As regards the particular details of the invention, that may be a matter of dispute to be settled in a court of law, as to the patents of 1841, the patents of 1843, and the patents of 1845—as to whether the one is a piracy or not of the other. Those are questions for the courts of law; but you have the inventions of Cooke and Wheatstone on the one hand, and the inventions of Mr. Bain on the other; and I say it is not a question of piracy which you properly do not enter upon, which these Committees and the Privy Council never enter upon; but it is a question on general policy as to whether extraordinary powers are to be given to the parties now asking for them, and from which the party opposing is to be excluded.

Sir, I have already observed on the fact, that there are thirteen patents to be summarily dealt with; thirteen patents extending over nine years. The alienation clause is to be repealed in respect of all those, and not only in respect of all those thirteen, but in respect of all others that have already been, or hereafter may be, granted, and that upon a case of this sort; for I say there is no evidence at all on the part of the promoters that will justify you in saying the preamble of this Bill is proved as regards public utility, or as regards the general powers necessary to carry it out.

Sir, I am happy to say, I have now almost discharged my duty in

addressing you. I have commented on the opening speech of my learned friend, and on the evidence given in support of the general case for the Bill. I have only to call your attention to one or more dates that may be material in considering the progress of the invention in its present shape. I have already remarked the first era, terminating in 1840, with Cooke and Wheatstone's patents; the specification of the last being enrolled in July, 1840, containing nothing respecting electric clocks, containing nothing respecting printing machines, but relating to a telegraph with several wires, and with a metallic circuit. And when my friend opened the case to you, as if the whole invention were new, why, so far as regards communication by electricity by several wires and needles, it is a matter of notoriety that books were published abroad, and that in this country, long before 1837, lectures were given on this subject, and therefore those patents were, as indeed appears by the specifications of the patents themselves, which recite the application of electricity to this purpose—those patents were improvements on the discovery of M. Oersted, in 1819, of electro-magnetism.

I have also called your attention to what took place in 1840, when Mr. Bain communicated his invention to Professor Wheatstone, and when agreements were entered into, that were not carried into effect. On January the 8th, 1841, Mr. Bain obtained his first patent, which was for electric clocks, the invention having been communicated to Professor Wheatstone in the preceding August. On the 7th of July, 1841, Messrs. Cooke and Wheatstone obtained their fourth patent.

In the obtaining of that patent, a material fact took place. I told you that since August, 1840, Professor Wheatstone and Mr. Bain have been in continual collision. There is a power in any one of the public to oppose a patent before the Attorney-General and in some subsequent stages. In the case of an opposition, the party who applies for the patent is obliged to leave a deposit, stating the nature of his invention, because it has frequently turned out that parties have enumerated in their specification, inventions they had not discovered when they obtained their patent. On obtaining the patent of July, 1841, Messrs. Cooke and Wheatstone's fourth patent (the first of the commencement of the second era, so to speak), there was a deposit with Sir John Campbell, and that patent was still for a metallic circuit. On December the 7th, of the same year, Mr Bain obtained his second patent. He was then opposed by Professor Wheatstone. The patent was opposed by Professor Wheatstone, and was refused in the first instance; but on Mr. Bain requesting that the deposit, which had been left with Sir John Campbell, of Professor Wheatstone's patent of July 7th, should be referred to, this patent was granted.

Mr. HILL—I must beg to know, what course we are pursuing. I am, as I before said, willing to go into the minutest details of every allegation contained in Mr. Bain's petition; but the Com-

mittee themselves have gone over the petition, allegation by allegation, and they have confined my friend to a particular part, which has been so often repeated, that every gentleman must have it by heart. My friend is now, in the last part of his speech, getting back to one of the early allegations. Let me only know what I have to do, and I am perfectly ready to do it. I will prove the priority of every invention claimed in every patent. I will prove that we infringe nothing of Mr. Bain's. I will disprove every thing my friend has said the moment he has given me a reason for doing it, by giving evidence of its truth. But if my friend is not to be permitted to go into this matter, is it not rather hard upon the two respectable gentlemen that I represent, that they should sit here to have statements made which, if they were true, would utterly drive them out of society, and justly so, as honest men and gentlemen, when my friend must know that the matter cannot, with any regard to the decision which the Committee has entered into, go beyond his statement, and never can be tested as to its truth or falsehood by putting witnesses into the box.

Mr. WEBSTER—If I believed I was travelling the least out of the course which the Committee prescribed to me, I should be extremely sorry. I undertake to prove that it is not for the interest of the public these powers should be given, that it is not for the advantage of the public that patents, which are practically useless, should be extended prejudicially, that is, should be enjoyed by a large body that will give them a sort of factitious influence they would not have on their own merits. The course that is now adopted by the Privy Council, is to take the state of the invention at particular eras, as disclosed in the specification or otherwise, without entering upon details. In order to enable you to form a proper estimate of the progress of inventions, and to show where the merit is, and how the public must be affected, it must be material you should know what has been the general history of the invention; but as to going to details, as to whether the patent of July 7th is a piracy on any that preceded it, that you will not do; you will entertain that question no further than this, to see what has been the course of the invention, so as to know how the public interest is affected. Now it is with that view, and with that view alone that I have troubled you at some length on these facts of the case, which, so far as I have opened them, and stated them to you, will be proved most distinctly by Mr. Cooper and Mr. Bain. In fact, some of them are already proved by Mr. Cowper and General Pasley, only the matter is left detached and broken. A few isolated facts have been proved; and am I to be told when the promoters of a Bill, who are to make out their case (and no one in the profession knows better than my learned friend Mr. Hill, whose experience is so great, that he can see into the mind of any counsel conducting a case of this sort), am I to be told when he has conducted his case in this way, so as to leave you in the dark; when he has called evidence to say that Mr.

Bain's invention, as compared with Professor Wheatstone's, is worthless; that Mr. Bain stole from Professor Wheatstone, and not Professor Wheatstone from Mr. Bain, that I am not to bring before you generally the progress of the invention; all I can say is, if that be so, it is a sort of injustice on the individual, and a sort of injury to the public that this Committee could never have intended; when the fact is, that in grants of this nature, and in any alteration of them, every encouragement is given to the public to come and oppose them, yet we are to be shut out on some technical difficulty of this kind.

Now, sir, I will give you the date of Mr. Bain's second patent, which is the 7th of December, 1841.

CHAIRMAN—Do you think it necessary to call our attention to the several patents? Can you not put them in as Mr. Hill did? You are going to call witnesses.

Mr. WEBSTER—In this patent of December 7th, 1841, there was the abandonment of the metallic circuit, and the substitution of one wire and the Electric Printing Telegraph. That was in 1841. That is all I have to say about it.

Then, sir, in December, 1842, comes Cooke and Wheatstone's fifth patent. There the metallic circuit was also abandoned, and there were other alterations similar in character to what I have last mentioned.

On the 27th of May, 1843, comes Mr. Bain's third patent, and this, sir, is a most material era. That invention was for one wire—one pointer (that which is before you on the table), and a complete set of signals, the earth making the circuit either with or without voltaic electricity. That was the invention that Mr. Cowper lectured upon in 1844, at the Royal Institution; so that you have in March, 1844, Mr. Bain—having done all he could to bring an invention before the public, having obtained a patent for it, and having furnished Mr. Cowper with information to lecture upon it—he is then publicly declaring himself to be the inventor of an Electric Telegraph of a single wire, a single pointer, and of a complete set of signals, the earth completing the circuit. After that comes the patent of Cooke and Wheatstone, of May 6th, 1845, their sixth patent; and it is between those two patents the question of litigation has arisen—with that I have nothing to do at all—I have only to remark, that upon the evidence you have distinctly before you, that in May, 1844, this disclosure was made to the public by Mr. Bain, of the invention that is now used—the invention that Cooke and Wheatstone themselves adopted as appears by their last witness; and in order to complete the catalogue, on the 25th of September of last year, Mr. Bain obtains his fourth patent. That is the history of the case with regard to the general principle of a single wire, and the abandonment of the metallic circuit, and a complete set of signals, with one signal plate, and the earth forming part of the voltaic circuit.

Now, sir, what are the general facts that appear before you, without entering into general details? That since 1840, inventions have gone on betwixt these two gentlemen, and that it has been brought to its present state and the invention now adopted is that of my client.

Mr. HINDMARSH—Nothing of the sort appears. However, I will not say any thing, because if one answers one thing, and does not answer another, it may be supposed we admit those things which we do not answer, therefore I will answer nothing.

Mr. WEBSTER—Those, sir, are the facts of the case. Many of them are before you, and some few others will be added by Mr. Bain and Mr. Cooper. It appears, then, that there are Professor Wheatstone and Mr. Cooke, having made certain inventions, possessing the command of society, for these gentlemen deservedly bear great reputation, and competing with a gentleman like Mr. Bain, having nothing to depend on but his own talent;—they come and ask for extraordinary power to be given to them to the exclusion of Mr. Bain, though the more perfect invention of Mr. Bain may be laid down at a cost less than one-half the estimate of Cooke and Wheatstone.

I say, sir, upon those grounds there is no case made for the preamble of this Bill, and that it is not a case in which you would prejudice an individual, while at the same time you confer no benefit on the public.

Mr. JOHN THOMAS COOPER was then called and examined.

Mr. ALEXANDER BAIN was called, and in the course of his examination upon the following question being put to him, and answer given, "Did you furnish the model?" "There was more than one model—there were two models that constituted the agreement. I finished one, and partly finished another," this discussion ensued.

Mr. HAWES—What is the object of this? Is it to show Mr. Wheatstone is not the inventor of the clock? If so, let us clear the room, and come to a resolution at once.

Mr. WEBSTER—I should submit that in considering the preamble of the Bill, and the question whether there is merit in the parties, so as to entitle them to alter the relative positions of Mr. Bain and of Messrs. Cooke and Wheatstone in the way this Bill will, that the state of the invention now, as compared with the state of the invention as it existed in 1840, after the earlier patents of Professor Wheatstone were taken out, is a material element for your consideration, and in order that you may have the proper materials for forming an estimate on the merit of the invention, and the state of the invention, and in what way these individuals will be affected by the passing of a Bill which will give considerable power relating to earlier patents, you must know the general course of the invention, what has been the invention step by step, and where the merit is. I submit to you that this is a line of evidence always introduced before Committees of this House, when questions as to the extension

of patents were before them, and that the Privy Council have invariably laid down that they would adopt some rules that Parliament had adopted.

Mr. HAWES—But Parliament has not said it will lay down the same rules that the Privy Council adopts.

Mr. WEB TER—I say, that when matters of this sort have been brought before Parliament they have been viewed with great jealousy, and Parliament has examined strictly into these matters.

Mr. HAWES—To what case do you refer?

Mr. WEBSTER—I refer to the invariable course in the Privy Council.

Mr. HAWES—You said Parliament adopted a certain practice. What is that?

Mr. WEBSTER—In the case of the Bills that were before them.

Mr. HAWES—If you allude to precedents you are bound to give us the precedents.

Mr. WEBSTER—In Watt's Act, 15 George III., relating to the steam engine, chapter 61, you will find there the recital of the public utility of the invention, and of the insufficiency of private means.

Mr. HAWES—I suppose we shall find that here.

Mr. HINDMARSH—In substance.

Mr. WEBSTER—The argument I address to you is this, and I was going to furnish you with five Acts of Parliament which are public statutes, where the preamble sets forth distinctly the special grounds on which the patent ought to be extended.

Mr. HAWES—This is not a question of extension of patent.

Mr. WEBSTER—But it is the same thing, substantially.

Mr. HAWES—Your cases do not apply. Since that time a special tribunal has been appointed.

Mr. WEBSTER—With great deference, sir, they do apply and for this reason: the course of practice was very well understood, and it is now to be found in the practice of the Privy Council in the extension of patents. I say this, though not a question of extension, is to be tried by the same rules, because a party is coming to ask for enlarged powers which he cannot have without the sanction of Parliament. Why does he ask for them? but on the ground that it is for the benefit of the public that they should be given. It was for the benefit of the public that the extensions were given.

Mr. HAWES—It may be for the benefit of the public, even though Mr. Cooke and Mr. Wheatstone had robbed Mr. Bain of every thing which they now have. We ought not to go into that, surely.

Mr. WEBSTER—Surely you ought, sir.

Mr. HAWES—If you say we are to try the priority of inventions, then that is contrary to the rule laid down by the Committee.

Mr. WEBSTER—I do not say you are to try it, as if you were a court of law, but you must try the priority in some measure; you would not surely encourage a fraud or grant a Bill if it is a useless patent.

Mr. HAWES—If you mean to say that by this Bill they will set up a company to make fools of themselves by invalid patents, and invest their capital in a shadow, the Committee will consider that by and by—whether it is a company that ought to be formed. If you show the invention as useless, and that it is utterly impossible a return will be made for the capital, and that the demand of 600,000*l.* capital is beyond all bounds, extravagant, and not to be sanctioned, then you give us good grounds for rejecting the Bill.

Mr. WEBSTER—Those are the points.

Mr. HAWES—But those are points which you have not addressed yourself to at all. If you will do that, we will sit for six weeks to hear you.

Mr. WEBSTER—No, I will not trouble you to do that, sir. All I say is, that to enable you to judge whether the inventions of Cooke and Wheatstone are worthless and useless, you must know the course of the inventions, and I take these gentlemen up at the earliest stage when they come into collision with Mr. Bain from August 1840.

Mr. HAWES—You said you would show that the inventions were utterly worthless and useless. Will you put in witnesses to show that the patents and the telegraphs of Cooke and Wheatstone are utterly useless and worthless. Show that and *cadet questio*, I don't think the House would sanction a Bill to form a company to carry out that which was proved to be utterly useless and worthless.

Mr. WEBSTER—It is not utterly worthless and useless in the abstract. I must show you that the inventions are worthless by the present state of inventions, and I can only show that by this gentleman.

Mr. HAWES—I wish to pay the greatest respect to Mr. Bain, but do come to something like evidence. Show us that the invention of Cooke and Wheatstone is bad, and show us that those of Mr. Bain will supersede it.

Mr. WEBSTER—I must begin at one end or the other. My case is to show that the inventions, of which Mr. Bain is the author, are infinitely superior, so superior that the inventions of Cooke and Wheatstone are worthless, commercially speaking. I do not care which end I begin at. I begin at the beginning, as being most convenient, but if you like I will examine him as to that model before you, and then take him back. I thought it right to begin at the earliest time when these gentlemen were in collision.

Mr. HAWES—What course is to be taken with the other gentleman? If you put in one Electric Telegraph to knock down the other then you will have another witness to set it up. Then we shall be in the midst of the respective inventions.

Mr. WEBSTER—But I am sure, sir, you will see that I am not to be excluded from bringing my client's case forward by reason of my friend having adopted a course that may be inconvenient. My friend opened a case really keeping all information back from you, calling neither Mr. Cooke nor Professor Wheatstone, and I can only

prove my case of the worthlessness of their invention by calling Mr. Bain.

Mr. HAWES—To prove that they have failed, and that their invention is worthless.

Mr. WEBSTER—Yes.

Mr. HAWES—Now we must consider what course we are to take.

Mr. WEBSTER—I beg there may be no misunderstanding as to the way I put the case. I do not say that in 1837, 1838, and 1840 those inventions of Cooke and Wheatstone were not good and valuable inventions, and that they were not more valuable than the inventions of Alexander, Davy, and other people, and that they were not the first persons who combined with the Railway an Electric Telegraph, but I further say that those inventions are, as compared with the inventions of Mr. Bain, worthless, commercially, Mr. Bain's being so much better. Now I thought it my duty to put the case clearly before you.

Mr. HAWES—The public will soon put a value on that.

CHAIRMAN—If they find Mr. Bain's is a good one they will employ Mr. Bain at once.

Mr. WEBSTER—But you prejudice Mr. Bain in a way that he will explain, and other witnesses will explain, if you grant a Bill of this sort, by which he is set at defiance.

Captain GLADSTONE—The promoters of the Bill have only to show that Cooke and Wheatstone's is a public benefit.

Mr. WEBSTER—Yes, sir, a public benefit means a public benefit with regard to the existing state of invention. Watt's first steam-engine was a public benefit at that time. The roughest locomotive that ever existed was a public benefit at the time it was first invented, but when it is compared with the latest improvements of Messrs. Stephenson, it would be absurd to say that it is a public benefit.

Captain GLADSTONE—They have to prove it is a public benefit at this time.

Mr. HAWES—If we go on and examine Mr. Bain as to his being better than Cooke and Wheatstone's, somebody else may come and say we have something better than that.

Mr WEBSTER—I believe there is no question but that the invention is in the hands of the gentleman before the Committee. I answer to an observation that was just made by an honourable member, that the promoters must show that it is a public benefit. I should submit that the House will not grant more extensive powers in respect of patents that are superseded.

Captain GLADSTONE—If yours is a greater public advantage, the public will avail themselves of it.

Mr. WEBSTER—That is not a principle that was ever adopted by the House, or that ought to be adopted, because what constantly occurs in practice is, that when a patent is worked out a company is obtained to bolster it up.

Captain GLADSTONE—What do you mean by worked out.

Mr. WEBSTER—Superseded by superior inventions. It is known to many gentlemen conversant with these things, that an Act of Parliament to form a company for the extension of a patent (except in the case of an invention like Mr. Smith's screw propeller) is not asked for till the thing is worthless. By means of the influence which an Act of Parliament gives, the thing can be kept afloat.

Captain GLADSTONE—Not if other patents have superior merit.

Mr. WEBSTER—Even then.

Mr. HAWES—What point do you mean to examine Mr. Bain upon? Will you begin by proving that the telegraphs of Messrs. Wheatstone and Cooke are worthless and useless? The point to which you now mean to examine Mr. Bain.

Mr. WEBSTER—Yes, sir.

Mr. HAWES—Then I think it is for the Committee to consider whether that ought to be allowed or not.

CHAIRMAN—Mr. Bain has one telegraph at work, has he not.

Mr. WEBSTER—Yes, sir.

CHAIRMAN—Then go into that and compare it with Cooke and Wheatstone's.

(*The examination of the witnesses was then proceeded with.*)

Mr. John Thomas Cooper called; examined by Mr. Birkbeck.

I think you are well acquainted with the science of electricity? I believe I am.

You have paid a great deal of attention to it? I have.

You lecture upon it? Yes; occasionally.

For how many years?—

Mr. HILL said he would at once admit Mr. Cooper was perfectly competent to give evidence upon the subject; there could be no doubt of it.

By Mr. Birkbeck.

Were you present at Nine Elms in the year 1844 when any experiments were going forward? I was there on one occasion.

Do you recollect when that was? It was, to the best of my recollection, on the 22nd of April, 1844.

Whose telegraph was that? Mr. Bain's.

Explain it. *It was a Printing Telegraph; at least, a machine for printing and passing signals at the same time.*

Do you consider that a printing telegraph is more useful than an ordinary telegraph? I should say so, generally speaking; but I have not much experience in those matters, as to the utility of one invention or the other. I should think that a thing which would register what is sent by it to be an advantage.

Was this telegraph exhibited under favourable circumstances? In relation to what?

Were the arrangements complete? I think they may hardly be

said to be complete, because it was put up in a temporary sort of way.

It was not a permanent telegraph? I conceive not. The arrangements made at the time were those that were, I should say, temporary, not permanent.

By the Committee.

An experimental trial? An experimental trial.

By Mr. Birkbeck.

How did it act on that occasion? It acted very well.

Is it of importance that the insulation of the wire should be good? I should conceive it was of great importance it should be so; as perfect as possible.

I suppose you would consider, if you had to report upon such an experiment as that, whether the insulation was perfect or not? I should say that the insulation in this case was not perfect. It was put up in a temporary sort of way, and I should say the insulation was imperfect; at least not so perfect as it might be made. There was no positive attempt to insulate the wire on this occasion—in the short distance that I examined it the wires were twisted round the posts.

What sort of posts? They appeared to me to be some old palings—some old fence—or something of that sort, put up on that occasion.

How high from the ground? I should say about four feet.

Old posts? Old posts, to the best of my recollection.

Were the wires not liable to injury? There was no protection. They were too low to prevent any person running against them, or any thing of that sort.

Did you consider this experiment a total failure? Oh! certainly not.

How was the electric current produced? The only part of the apparatus for making the current I saw was some plates of copper tied together with some wires, and these plates of copper were thrown into a ditch at Nine Elms. I did not go to the Wimbledon extremity, but there were a quantity of copper plates tied together with wires, and these copper plates were thrown into a ditch in the neighbourhood of the Nine Elms station.

Was there any voltaic battery used then? None.

Then how do you presume the current was produced? Why it must be presumed, because I did not see the other extremity, and therefore I presume that the zinc plate must have been put into the earth in some other position, at Wimbledon probably.

Are you aware that an electric current can be produced in such a manner? I saw it on that occasion. Until that occasion I was not aware that putting into the earth a plate of zinc at one position, and a plate of copper into it at another at certain distances from each other, would produce a current; *it was new to me at that time.*

What do you do with those two plates? These *two plates are connected together by wires or a wire.* For instance, *suppose this pen which I hold in my hand* to be the wire, and these two sheets of paper the plates, the current of electricity will pass through the wire in one direction, and through the earth in another: supposing the plates to be both in the earth, and the pen to represent the wire, the current of electricity set up will pass along the wire and through the earth, or through the earth and return by the wire.

And you believe the electricity by which that telegraph was worked, was produced in that manner? I have no doubt about it whatever, though I did not see the zinc plate immersed.

Whose discovery do you consider that to be? Mr. Bain's.

Did you ever previously hear of it? I never heard of it till that time.

Mr. Hill.

Which discovery are you speaking of?

The production of the current of electricity by immersion of plates of dissimilar metal in the earth.

By Mr. Birkbeck.

You have little doubt that is Mr. Bain's invention? I have no *doubt of it in my mind. I have not* heard any thing *to convince me to the contrary* of the *opinion I thus formed.*

Is that a distinct discovery from the other discoveries we have heard a good deal of—that the earth will complete a voltaic circuit? You mean the discovery of Steinheill?

Yes? Yes, I conceive it to be a distinct discovery from that of Steinheill.

I believe you are aware that General Pasley stated the other day that the substitution of the earth for the metallic circuit was discovered by Dr. Watson. Do you know what Dr. Watson discovered? I do not, only as a matter of history.

If General Pasley said this—"The principal discovery which Mr. Bain claims was made by Dr. Watson in 1748." Is that true? You must tell me what it is that Mr. Bain does claim, and then I can answer the question. If Mr. Bain claims the introduction into the earth of a plate of copper and a plate of zinc, then I should say that Mr. Bain is right in his claim; because certainly Bishop Watson could not know any thing at all about such a thing—his had been prior to the discovery of galvanic electricity.

You mean Dr. Watson's book? I have never seen Dr. Watson's book. I have hunted all over the essays, and I cannot find any record of it there; but if Dr. Watson discovered it in 1748, as I understand it has been stated that he did—

Mr. Hill begged to interpose.

His learned friend, Mr. Birkbeck, had been speaking of one thing, and General Pasley of another. General Pasley spoke of

completing the circuit by water, or by means of earth, so that a single wire connected with the earth or water at both ends, gave a perfect circuit. That was what General Pasley had spoken of, and not the generation of electricity or galvanism, by thrusting different metals into the earth. With respect to the last, it might or might not be that Mr. Bain was the discoverer of that. He (Mr. Hill) did not want that, and Mr. Bain was welcome to the merit of the discovery. What he had asked General Pasley about was, the power of completing a circuit when you had got half the circuit, by means of water or by means of the earth.

The Witness.

Common electricity?

Mr. Hill.

Mr. Cooper knows that is old.

The Witness.

As old as the hills as relating to common electricity.

By Mr. Birkbeck.

Is not that which we have just been speaking of, Mr. Bain's invention? *The invention, if I understand you, of the production of electricity, by placing two different metals in the earth, I consider to be due to Mr. Bain.*

Now I will read to you what General Pasley said: "The principle was, that an electrical circuit may be made by water or the earth, using only one single wire. That water or the earth are electrical conductors, and therefore that one wire, with one plate of zinc at the extremity of one wire, buried in the ground or immersed in water, and with another plate of copper put into the ground or water at the other end of the wire, near the electrical machine and voltaic battery, will make a perfect circuit, instead of using two wires, which had been considered necessary before." Now I wish to ask you whether it makes the least difference whether you put in a plate of zinc at one end and a plate of copper at the other—or two plates of zinc and two plates of copper? It makes no difference at all.

What should you say if you did not know this evidence had been given by General Pasley—should you say the person who gave it was acquainted with the principles of voltaic electricity? Why, I should be very sorry to give an opinion on a matter which would affect in any degree the reputation of General Pasley.

What should you say if you did not know by whom it was given? I should say from what you have just read to me, that it appears to me to be jumble, I can hardly understand it, I really cannot understand the question, or what the plate of zinc and plate of copper have to do with the electrical machine. He is talking of voltaic electricity in combination with frictional electricity.

The General is ?—Yes.

If General Pasley stated his impression to be that Mr. Bain had borrowed from Messrs. Cooke and Wheatstone—

Mr. Hill submitted that if Mr. Birkbeck wished to ask any question to contradict General Pasley he must read the General's evidence.

Mr. Birkbeck was perfectly willing to do so.

Now the General said, "I ought to have mentioned that on comparing the printing telegraphs of Mr. Wheatstone and of Mr. Bain, that Mr. Wheatstone's printing telegraph worked three times as quick as Mr. Bain's, and there was an assertion made by Mr. Finlaison and Mr. Bain that Mr. Wheatstone had copied, or had appropriated his printing telegraph, that he had taken the idea from him, and Mr. Wheatstone's appeared to me so much superior, that I thought, if there was any copying in the case, that Mr. Bain had copied from Mr. Wheatstone, and not Mr. Wheatstone from Mr. Bain." Now I wish to ask you whether that is your opinion also ? I have never seen Mr. Wheatstone's printing telegraph in action.

Have you seen it in the specification ? Yes, I have seen his specification.

What conclusion did you come to ? I cannot say which has the priority of claim. I cannot recollect at the present time which is the prior patent.

Is there any similarity between them ? There is some similarity.

Did this telegraph which you saw at Nine Elms give signals ? Yes, it did.

Will you be kind enough to describe how it gave signals ? By a circular dial-plate, which had certain figures upon it, and the signal was transmitted. For instance, I requested a certain message to be sent, and I gave, I think it was the 22nd of the fourth month, 1844, that was the 22nd of April, 1844. I requested that might be sent. It was printed when the message was sent and it was printed when the message was returned, and I had that piece of paper until within a very short time.

I believe that was not the paper (handing a small piece of yellow paper to the witness)? Something like this. This was not the message I think I sent. I sent two messages. This may be one : but one I recollect perfectly well was the 22nd of April, 1844. I have that, but have unfortunately left the book at home in which it is placed. I have not brought it here to-day. It transmitted the signal, it was sent to Wimbledon, and the paper printed was put into my hands, and I was asked if that was the same message I sent.

By the Committee.

Is that the same paper ? No; it was something analogous to that· (Mr. Bain explained the working of a model to the Committee.)

By Mr. Birkbeck.

Are you acquainted with any more perfect form of Electric Telegraph than that? I never saw that model until this morning. Therefore I have not had time to examine it attentively; but it appears to me to act remarkably well, very quickly and very steadily.

Do you consider Mr Bain has made any improvement in Electric Telegraphs?

Mr. Hill inquired what that had to do with the issue which the Committee had stated they would confine the inquiry to.

Mr. Birkbeck submitted that it had a great deal to do with it, for it bore directly upon the very issue which the Committee had mentioned, because he would show the Committee that through the competition of this Company those great improvements which had hitherto been made in Electric Telegraphs would be put an end to if this Bill were to pass.

Mr. Hill was willing to go into the whole inquiry, if it were thought necessary to do so, but he was only anxious that his client should not be prejudiced by any piecemeal inquiry. If Mr. Bain had made an invention which was not included in any of Messrs. Cooke and Wheatstone's patents, he would have a right to exercise his invention after the Bill was passed, and if it were an invention that superseded all that had gone before it, and he had a right to practise it, all the Acts of Parliament that could be passed, all the power of government, all the power of commercial interest could not, thank God, prevent such a useful invention coming into full play.

By Mr. Birkbeck.

You know something about the progress of inventions? Relating to Electric Telegraphs?

Inventions generally? Yes, I do.

Do you think if this Bill had been passed five or six years ago Mr. Bain would have been so likely to make these improvements?

Mr. Hill—Really this is imagination double distilled. I trust the Committee will lay down some intelligible rule of inquiry. I shall be happy to follow it, but this Jack-o'-lantern sort of investigation I really do not know how to meet.

By Mr. Birkbeck.

Do you consider that Mr. Bain made improvements in Electric Telegraphs? Yes, I do.

Very considerably? Yes, I do.

Do you know whether asphalt is a good non-conductor of electricity? I know that it is a non-conductor of electricity, it is a very perfect non-conductor of electricity.

Do you consider it a good mode of insulation to support the wires or to case the wires in asphalt? Yes, I do.

Cross-examined by Mr. Hill.

With regard to this experiment in 1844, you say you do not consider it a complete failure? *No, I do not consider it a failure at all.*

What did it do? *It transmitted a message to Wimbledon and brought me the answer back.*

That is to say, you stood there and were told so, that is all you know about it, as you did not go to Wimbledon? No, I could not be in two places at once.

By the Committee.

What was the interval of time? I did not take particular account of the time, but it appeared to me not to work so rapidly as I should have expected to have seen it; but then it had two operations to perform, it had to transmit a message, and had to print it.

What was the interval do you think, speaking as near as you can? I should think somewhere about two or three minutes.

By Mr. Hill.

Did you note it at all? I did not.

Can you tell whether it was six minutes and a half? This, which is on this yellow piece of paper, was not the message. This may be one of them, but this is not the one I am particularly alluding to, I don't know whether I sent this message or not; I recollect the other because it was the 22nd of April, 1844; that I recollect very well.

And do you mean to say that you did not note, nor that any body noted the time it took to send and return the message? I did not, only it appeared to me to be rather tardy.

What did you compare it with when you considered it rather tardy? With what I expected to see.

Had you seen Messrs. Cooke and Wheatstone's on the Great Western? I don't think I had at that time.

But you had heard accounts of it? Yes, I knew perfectly well the motion of Electric Telegraphs in general.

Was General Pasley there? No.

Who was there? There were two other gentlemen, I do not know their names, I never saw them before, and do not think I have since.

Friends of Mr. Bain? They may have been. I don't know; Mr. Finlaison was there; but independently of Mr. Finlaison, there were two other gentlemen there, but I do not recollect who they were; I understand they came from one of the government offices, and that is all I know about it.

Mr. Alexander Bain called. Examined by Mr Webster.

Are you a native of Scotland? I am.

Did you serve your apprenticeship to the business of a watchmaker in Edinburgh? Not in Edinburgh, in Wick.

A town in the North of Scotland? Yes.

About the year 1837 did you come to London? Yes.

With what object? To follow my business as a watch and clock maker.

I believe about that time your attention was directed to the application of electricity? Very shortly afterwards.

Was that on hearing a lecture? Yes, at the Adelaide Gallery.

Did it strike you that it was applicable to your business? It did.

Now, some time after that I believe you made some applications of it? I did.

What was the first you made? The first was an endeavour to move clocks with it.

Did you succeed in moving clocks by electricity? I did.

The application of electricity, as a moving power of machinery, had then become a matter of experiment? My attention was not drawn to it for the purpose of moving machines to work instead of steam, until afterwards; but the little machines in the Adelaide Gallery were moved by rotating magnets.

You have spoken of having made your invention relating to clock-making. Did you also make an invention relating to Electric Telegraphs? Afterwards—after the clocks.

Was that about the same time? Shortly afterwards; very shortly.

What was the nature of the invention relating to the Electric Telegraph? It was to make a printing telegraph.

Was the object of that to print by the current, or by the machinery moved by the current? My first object was to print by the current; but at that time I was not so well acquainted with the power of the current when sent through a long wire.

What was the first machine that you made? How was the first machine made that you constructed? The first machine that I made at all, was a wheel with types upon it, to be worked by an electro magnet.

Did you, about that time, make a machine with types, that would print a message? Yes.

I do not want you to go into the details of that machine: I believe, at that time, you had not funds to enable you to bring it forward? I had not.

You were a journeyman watchmaker? Yes.

The only resources you had were what you earned in your trade? I had no other resources.

Did you make application to Sir Peter Laurie? Yes, a considerable time afterwards—after I attempted the first machine.

What was the earliest time at which you constructed an electrical machine for printing, of the kind you have described? In 1840: it was then I overcame many difficulties which I had met with before.

You made an application to Sir Peter Laurie? On the 1st of August, 1840.

Had you made this machine, so that it would work, some time

before that? Yes: I may mention here that I had several pieces of machinery at that time; it was not confined to one or two, there were several.

I wish to know how long before your application to Sir Peter Laurie, you had satisfied yourself of the practicability of making an electrical printing machine? A considerable time before.

Two or three months, or how long? Many months.

Was it early in that year? I think I was satisfied of the practicability of it before 1840.

Then you applied to Sir Peter Laurie on the 1st of August, 1840? Yes.

You had an introduction to Dr. Birkbeck? I did not see him.

Did you apply to Mr. Baddeley, the editor or assistant-editor of the Mechanics' Magazine? I did.

Were you recommended by him to go to Professor Wheatstone? Yes, by Mr. Baddeley I was.

Had you at that time any knowledge of the Professor? None.

Did you go to him as a man of science? I was recommended to go to him by Mr. Baddeley.

At what date did you go to him? The same day, the 1st of August.

Where did you see him? At King's College.

At that time had you seen any of the specifications of Messrs. Cooke and Wheatstone? None: I did not know that there were any.

You were not acquainted with their invention? Quite unacquainted.

What passed at that first interview with you and the Professor? There was an appointment made. I explained my invention to Professor Wheatstone, and there was an appointment made for another day, when I was to call at Professor Wheatstone's house.

There was nothing done that day but an appointment made? No.

When did you see him next? I think on the 18th of the same month.

Did you explain to Professor Wheatstone, the first day, the nature of the invention? I explained the nature of the two inventions—the Electric Printing Telegraph, and the electric clock. I partially explained them; I did not explain them very fully.

You did not take the model with you? No.

Did he at that time say any thing to you about any invention of his own, relating either to the electric clock or the Electric Telegraph? Not the Electric Printing Telegraph: he spoke of other telegraphs, but not of printing telegraphs nor of the electric clock.

Did he say any thing of an invention of the kind you described to him? No.

Was the next appointment at his house? As far as I can remember.

Did you see him then? I did.

Did you take any thing with you? Two models.

What models were they? A rough model of part of the printing telegraph, and a model of a portion of the electric clock.

What passed on that occasion? Professor Wheatstone bought the model of the printing telegraph I had with me.

What did he give you for it? Five pounds then; and there was a written agreement that I was to receive 50*l.* as soon as Professor Wheatstone made use of it.

As soon as he applied your printing telegraph to his telegraph, then you were to have 50*l.*? Yes, 50*l.* more.

Was any agreement made then or at any time about the electrical clock? None.

Was any thing said about the electrical clock? I brought a model with me and showed it to Professor Wheatstone—

The Committee thought they had nothing to do with any private conversation that might have passed between Mr. Bain and Professor Wheatstone.

By Mr. Webster.

An agreement was made on that occasion that you should furnish a model for 150*l.*? That was afterwards.

On another occasion? On another occasion.

Did you furnish the model which was part of the agreement? There was more than one model, there were two models that constituted the agreement. I finished one and partly finished another.

The Committee could not see that any useful object would be gained by this line of examination.

A long discussion ensued, which terminated thus—

The Chairman—Mr. Bain has one telegraph at work, has he not?

Mr. Webster—Yes.

The Chairman—Go into that and compare it with Messrs. Cooke and Wheatstone's.

By Mr. Webster.

You, I believe, have erected a telegraph between Glasgow and Edinburgh? I have.

How many wires has that? One wire.

Is that a metallic circuit or does the earth complete the circuit? The earth completes the circuit. The wire is one-half of the circuit, and the earth is the other half of the circuit.

Is that different in that respect from what has been referred to here as the metallic circuit as described in the earlier patents of Cooke and Wheatstone? Yes.

It is different in that respect? The patents of Cooke and Wheatstone prior to 1842 had what is termed metallic circuits, that is, two wires.

What was the cost of putting up that telegraph between Edinburgh and Glasgow? The contract is 50*l.* per mile.

Have you been paid for that as it has gone on? I have.

Have you heard any complaint respecting it from the Company or other persons? None whatever.

Has it answered to your satisfaction? It has.

You have told us the cost and you have told us that it is a single index? There is a single pointer with two signals.

Was the contract profitable to you? Yes.

Would you take any number of miles at the same price? I should be glad to take any number I could get at the same price, and it would yield a good profit.

You were paid as it went on? You are not a man of considerable capital? No; I was paid as it went on by the Company.

You say you put up at a good profit a single wire and not a metallic circuit. Had it a complete set of signals with a single signal-plate? The instruments there have each a single pointer, and two signals, I and V.

Does that I and V telegraph accurately represent the one at the Glasgow and Edinburgh Railway? Yes; I call it the single wire and the single index telegraph.

Does that one on the Edinburgh and Glasgow Railway work at intermediate stations as well as at the extreme stations? Yes.

How many—do you know? Seven intermediate stations.

Now with what rapidity will that work? About from twenty-seven to thirty letters of the alphabet per minute.

I wish you to compare that with the invention of Messrs. Cooke and Wheatstone on the Blackwall Railway? I have not seen Cooke and Wheatstone's, or rather not examined Cooke and Wheatstone's telegraph on the Blackwall Railway.

You know now, I suppose, the invention described in their specifications? Yes, I do.

I wish at present to confine you to the metallic circuit. The first three, I believe, relate to the metallic circuits? The first three or four. I think there are four.

What is the difference in the expense of construction, or convenience of a single wire of that kind and the metallic circuit of Cooke and Wheatstone? There is very great difference.

Describe them in your own way? In the first place, Cooke and Wheatstone's telegraph with metallic circuits requires two wires. There is the double quantity of wire used; there are also two needles used.

Do they work with less power than your's work with? When the earth is used as half of the circuit, the telegraph works with less power than where there is a complete metallic circuit.

And with respect to the rapidity of working? The rapidity of working I should say would be the same.

I believe you have several further improvements which is the matter of the last patent you have taken out? I have.

Are those considerable improvements on any thing which has pre-

viously been in use, or which is now in use? They are improvements, or rather I consider them improvements on every thing that I knew before of the same kind.

By the Committee.

What is the date of your last patent? 25th of September, 1845.

By Mr. Hill.

That is not yet specified? No, it must be specified in a very few days.

By Mr. Webster.

Will those improvements of this last patent enable you to give a much greater number of signals in the same time? Much greater.

What is the number of signals that can be given? There are two arrangements I have for giving signals; one arrangement is to spell words merely by the letters of the alphabet, which is exceedingly rapid compared to every other method that I am acquainted with, and as far as I can imagine, I can transmit them at the rate of about fifty or sixty letters of the alphabet in a minute. That is one method.

According to one method you transmit the signals at the rate of fifty or sixty letters in a minute? Yes; according to another method I arrange the signals on tables, and these tables are folded opposite to each *other, like the leaves of a book.* The signals are in squares on a table. Now I mean to use sentences or words in these squares and the tables altogether, about thirty-four of them, will contain an immense number of words,—in fact almost the whole of the language.

The whole of the English language? Yes, they may be taken either in sentences or in words.

Then you will be enabled to combine words? To combine words, yes. There are words in each square, for instance. I can combine the words—

You will combine words so as to read sentences instead of reading letters? Yes, instead of spelling the words.

Can you compare the rate at which intelligence can be transmitted by the means you have last described with the rate at which it can be done by the other? No comparison can be drawn between them, because the table of sentences will transmit perhaps about from twenty-five to thirty sentences in a minute—full sentences.

I believe you are able, when required, to explain to the Committee in detail how that is done? It is done in this way. There are two actions on the machine; by reversing the currents of electricity, I show any one of two sets of signals; I take two actions: instead of making the electricity act on a single pointer, I make it act on two magnets; I thereby run one point along the top of the table, and the other down the left-hand side. By these two actions, I can run both of the pointers together, one along the top of the table to the right, and the other down the side at the left; or I can

run any one I like of them; I can run the one at the top along, or the one at the side downwards.

You say by that means you can transmit intelligence in words and in sentences, with almost inconceivable rapidity? Yes; I may remark here to illustrate it further, the table is divided into squares by lines downwards and across; when the pointer is opposite any line at the top, it shows the whole line downwards, and at the side, the lines across, and where the lines intersect each other, the sentence or word is found.

By the Committee.

Have you made experiments on the new patent? I have.

Quite sufficient to satisfy you? Yes.

On a railway? No; but I know the current of electricity is the same that I use in the Edinburgh and Glasgow Railway forty-six miles. The current of electricity which I use in this I and V telegraph, will, I know, do for the new one.

By Mr. Webster.

I believe your specification is due to-morrow? On the 25th; yes.

Have you the complete working drawings of this invention already prepared? I have.

It is not a matter of policy or prudence to publish things of this sort until you are obliged to enroll them in your specification? No; I do not do it generally.

You tell me that this is working. I presume upon the single wire, and the earth used as half the circuit? Yes.

When was that first used for telegraphic purposes in England? It is a difficult question for me.

Did you hear Mr. Cowper's evidence? I did.

Was the telegraph on which he lectured comprised in your specification, or patent, of the 27th day of May, 1843? It was.

Then in respect to the single wire and single signal-plate, or needle, and the earth forming the circuit, as the one on the Edinburgh and Glasgow—is that invention and the one you have just described as the subject of your patent, the same? In principle.

I limit it to a single wire and non-metallic circuit and to a single needle? The expense of fitting up the new telegraph on the railway will be the same as the one I have fitted up. The wire the same; the posts the same, and so on.

I wish to have a distinct answer to this question, that in respect to the mode in which it is worked, as regards the electricity, it is the same as that described by Mr. Cowper, and contained in the specification of your patent of 1843? There are two ways of working the patent of 1843; one is by the electric current of the earth, and the other by the currents produced either by a voltaic battery, or by a magneto-electric machine, or by thermo-electricity, or any thing of

that kind; any such currents produced in any of those ways requiring to be transmitted through the circuit—

I do not wish to go into the details of that. This is the only patent you have taken out since 1843? It is.

You told us the expense of the telegraph on the Edinburgh and Glasgow Railway was 50*l.* a mile? Yes.

Would the expense of this last improved patent be more or less than that, or the same? On the railway it would be the same; but the telegraph instruments in the station would be more.

By the railway you mean the posts, and the wires, and the insulation? Yes, they are the same, in point of expense, by either patent.

What would be the difference of expense of the apparatus? They would be, perhaps, from 50*l.* to 60*l.* difference for each instrument.

Do you mean that 60*l.* would do it? Yes; that instrument, which you see there, I could make for 12*l.*; and the other, I consider, would, before I am remunerated properly, cost 70*l.* I mean the tables, and the arrangement of the machinery to work them.

The cost of the telegraph on the Edinburgh and Glasgow Railway, when complete, was 50*l.* a mile? Yes.

Well, I want to know for what you would contract per mile, for a distance of forty-six miles—I want to know what you would charge per mile, to lay down your most improved form of telegraph? The telegraph on the railway itself, not the instruments in the stations, but the laying down the wire on the line, will cost just the same, 50*l.* per mile.

I will take it another way. What will the indicating apparatus cost on the Edinburgh and Glasgow Railway. 12*l.*

What will that cost in its most perfect form? The same.

Of the last patent, I mean? About 60*l.* or 70*l.*

Now, if you had a contract offered you for 100 miles, what would you lay down your most improved form at per mile? 50*l.* per mile.

If you had so large a contract for 100 miles, you would lay it down in the most improved form of your last patent at 50*l.* a mile, and get a profit too? Yes.

Now, you have heard described the Rheotome? Yes.

That is one of the subjects of Cooke and Wheatstone's patent? It is.

What is the defect of the instrument? The practical defect in the instrument called the Rheotome?

Mention the practical defect? It is that the signals do not show correctly: for instance, if A is shown at London by that instrument, B might be shown at another station while A was shown at London.

By the Committee.

Do you mean at the same time? At the same moment—it is liable to this error.

By Mr. Webster.

I believe it is important to have some check observed at the end? Yes.

You have that in the Rheotome? No.

Have you it in your apparatus? Yes. I thought you meant the telegraph that was tried on the South Western Railway.

By the Committee.

That is the one you are speaking of? Yes.

By Mr. Webster.

Is that a printing telegraph? Yes.

You spoke of some defect that the Rheotome was subject to? Yes.

What is the nature of that defect? It is a machine which is very liable to go wrong; and the defect is, that if it once goes wrong, there is no means of ascertaining that it is so, and it will ever after remain wrong.

Is that a fatal objection to the general use of the instrument? I consider it so.

Will that sort of defect occur in your instrument at Edinburgh and Glasgow? No; because it is on a different principle: it does not occur in the deflecting needle telegraph at all.

I was asking you respecting the check on the observer; is that to be done by the printing telegraph? Yes.

Do you know if the Rheotome is in use on railways? I don't know.

Since 1843, the date of your patent of May 27, have you been continually improving the telegraph, till you have brought it to this improved state? I have.

Now your attention has been called to the clause in this Bill, with reference to breaking up streets, and so on? Yes.

In what way will that affect you, if you have not the same power? I consider it would affect me in this way; that if I get a contract, we will say, for instance, from London to Bristol—I get this contract, and make an arrangement with the railway to lay it down on this line—the Great Western Railway—I might lay down the whole distance on this railway; but if this Company get this Bill, I should be prevented opening the street, and bringing it through the centre of the town where the offices might be conveniently placed.

By the Committee.

How would you be prevented from opening the streets? I might not actually be prevented; but it is very likely that those who required the telegraph would apply to the Company that have the power to open the streets.

By Mr. Webster.

In order to lead the telegraph through towns, must you have the power to open the streets? Yes.

Do you think that you would be excluded from laying your telegraph on railways if this Bill should pass? Yes.

Is the advantage of the powers that this Bill will give to the Company, such that, in your opinion, you would be practically excluded from introducing your improved telegraph? I think I should; at least, to a great extent. I might have a little to do, but very little to what I might have if it was fair single-handed competition.

Do you know that inventors, without considerable funds, are very much prejudiced by competition with people who have funds? I do.

Have you experienced considerable difficulties yourself in England, from the influence of these gentlemen, Messrs. Cooke and Wheatstone? I have, indeed.

By the Committee.

Up to this time, you have found they have obstructed your invention? I have.

And seriously? And seriously.

By Mr. Webster.

How have you been obstructed? By the influence that these gentlemen have in England with railways:—and the society that Professor Wheatstone has moved in, the Scientific Society, has obstructed me very considerably—at least, I consider so: I may be mistaken; but I consider I have been, because I understand that rumours have been put out frequently, very frequently, that my telegraph was not any thing like so good as his telegraph, or Cooke's telegraph; and these rumours were kept up among that portion of society in which I did not move; and their position in society had influence, which operated against my getting orders for telegraphs.

I believe you have also been met with threats of legal proceedings? I have from Professor Wheatstone, not from Mr. Cooke.

Now, I ask you whether these complete improvements have gone on progressively from the time of your patent in 1843—have the series of improvements that have led to this complete one, gone on progressively from 1840? Yes.

Have you seen lately the telegraph put up at Derby and at Croydon? I have seen the telegraph at Croydon, and a portion of that which is being put up at Derby; it was not finished at Derby. I have seen a telegraph instrument at Derby.

Is that the same that you have described? Yes.

It is not put up by you? No.

Do you know who it is put up by? I was at Derby, and the

engineer, Mr. Barlow, told me it was put up by Cooke and Wheatstone.

Is that the same as the subject of your patent in 1843? I consider it the same.

By the Committee.

How many have you put up altogether? Only the one on the Edinburgh and Glasgow.

How long has that been working? Several months.

How long; state precisely? Nearly three months.

Is any official report made of it? Not yet.

I understand you to say you have heard of no complaints? No.

And that it works perfectly satisfactory? Yes.

And perfectly correctly? Perfectly correctly.

By Mr. Hill.

And that was put up at 50*l.* a mile? Yes.

By the Committee.

Is it intended at the expiration of any period that any report should be made? It has not been said that there would be a report, nothing has been said respecting it.

Cross-examined by Mr. Hill

You say it has been at work three months; are your wires carried under the ground by asphalt according to your invention? No.

Are they carried above the ground on posts? They are carried on posts.

Is it a printing telegraph? No.

Now, you have an invention for moving the coil and not the needle, the needle being Cooke and Wheatstone's invention? I don't understand you.

You have an invention for moving the coil in giving the signal, instead of moving the needle to give the signal? I have.

Do you understand that? Yes.

Moving the coil instead of the needle was your own invention, moving the needle being Mr. Wheatstone's invention? No, the moving of the needle is, I understand, Professor Oersted's, of Copenhagen.

Is it not your own? I don't claim it.

But the coil you did claim? I did.

What do you use on the railway at Glasgow? I claim—

Never mind what you claim, what do you use? I use, not the needle but two circular magnets, mounted on an arm of brass.

Then you use some third apparatus, neither needle nor coil, is that it? Yes.

It is a mere substitution for a needle is it not? I don't consider it so.

Now we have heard a great deal of your discovery, that the earth generates electricity and galvanism; in your railway do you use that discovery or do you resort to a voltaic battery? I use voltaic batteries.

Do you use the alarum which you have described there, or do you use an alarum upon similar principles to those of Messrs. Cooke and Wheatstone? I do not.

Which do you not? I do not use Messrs. Cooke and Wheatstone's alarum.

Do you use the one you have described? The model that is there do you mean?

Do you use one like that model? I don't understand you.

When I came into the room last, you were explaining a new signal, do you use the new signal now on that railway? Yes.

What you call I and V? The single wire and single index I call it. It is very often called the I and V telegraph.

Now you have told the Committee that generating or obtaining your electric, or magnetic, or galvanic power from the earth is not so powerful as by a voltaic battery? By the voltaic battery there is a greater command of power than from the earth.

It is more certain in its application, is it not? No, what I mean is, that by the voltaic battery I can produce it to any extent I require; but by the earth I cannot produce it to that extent, but to the extent it is produced it is more certain, far more certain than the voltaic battery.

What extent can you produce it to? I have produced ten miles.

But you cannot the whole distance between Glasgow and Edinburgh? No.

By the Committee.

Forty-five miles? Forty-six.

By Mr. Webster.

I forgot to ask you one question; did you hear General Pasley's evidence respecting the experiments on the South-Western Railway and at your house? I did.

Was the General correct as to what he stated about your having used a voltaic battery at the South-Western Railway? No, quite incorrect.

Was the insulation there perfect? No.

Was it any thing more than an experiment to show the practicability of the printing telegraph? Nothing more than an experiment.

No voltaic battery at all there? There were voltaic batteries at the station that I experimented with, but I did not work the printing telegraph with the voltaic battery at all.

By Mr. Hill.

You had a voltaic battery there? I had several.

Was that experiment with reference to laying down the telegraph from Nine Elms to Portsmouth? I don't understand you.

Was the object of the experiment to convince General Pasley, and the other gentlemen employed by government, that you by your plan could lay down a telegraph from Nine Elms to Portsmouth, was that the object of the experiment? The object was to show that the currents produced by the earth could print; that from the currents of the earth I could print messages backwards and forwards; the distances were not stated. I did not know what distance at that time it would print.

Did you not know that government was entering into these experiments for the purpose of choosing what telegraph should be laid down between Nine Elms and Portsmouth? I did.

Did you know at that time, that the power of electricity obtained from the earth, and without the use of a galvanic battery, will only run for ten miles? I was not aware at that time it would run so far. I found it to run six miles very well there.

Now your telegraph, I think you say, has only one wire? Only one.

Is there no use at all in having several wires?—Is it utterly useless to have several wires? I consider it utterly useless to have several wires for one telegraph.

But what I want to know is, in laying down what we call a telegraph, is it not important to have several wires, although each wire with the earth may complete a circuit? I don't understand.

Suppose you take it right away; suppose that you use a plan of double wires for the purpose of completing the circuit: are there not many cases in which it is useful to have four or two sets of such wires? Yes, if you require four or six telegraphs.

If you want a plurality of telegraphs, it is useful to have a plurality of wires? Certainly.

That is true? Certainly.

Now, I ask you, is it not very important to have a plurality of telegraphs combined with one apparatus? That depends on the amount of intelligence to be transmitted.

No doubt of it; but I suppose you have not laid down this telegraph, prosecuting all this labour and invention for so many years without being able to give me a practical answer. Are there not a great many cases in which it is absolutely essential to have a plurality of telegraphs? Only when one telegraph will not do the work.

But is not that a common case? Not that I am aware of.

Now do you not happen to know that the government telegraph from Nine Elms to Portsmouth, has two telegraphic communications and not one? Don't you know that? No, I do not.

Now, were you not in the habit of going to the Great Western termini, to see how Cooke and Wheatstone's telegraph worked? I went twice to the Paddington Station of the Great Western

Railway after I showed my own telegraph on the South-Western, but not before.

Then do I understand you to say, that you never saw Cooke and Wheatstone's telegraph at work at the Great Western Railway, until after the year 1844? Never.

Have you never been to Blackwall? Never, never at all.

Never at all to Blackwall? No.

Then you do not know that Cooke and Wheatstone were in the habit of working a single wire with the earth to make a complete circuit long before your patent? I did not know it at all.

You never knew it till this moment? No; I saw it specified about three months ago.

What was the date of the specification? I don't remember the date exactly, but I think it was after January last that it was lodged in Scotland.

You have watched the progress of these patents; I suppose, carefully, have you not? I have.

Do you know if Mr. Wheatstone, in the name of another person, according to the law of Belgium, took out a patent? I was quite ignorant of it.

You will be surprised to find this use of a single wire, together with the earth, to complete a circuit specified in a patent in the year 1841, would you not? I did not know of it.

Do you read French? No.

Now you tell us you can make a telegraph for 50*l.* a mile? Yes.

That is as good or better than any of Cooke and Wheatstone's? That is my opinion.

Better? That is my opinion.

A great deal better? A great deal better.

But you are afraid that if these gentlemen have the power of opening streets and you have not, that then you will not be able to lay down a telegraph, even upon railways and for railway purposes? I am afraid I should be greatly restricted in the number I should get.

Restricted in the number of telegraphs for railway purposes? Yes.

Do you consider that it is so very important, that the streets should be open for the purpose? I think it is the best way of laying down a telegraph in a town.

And you think the advantage of opening the streets are such as to make railway companies, and other persons requiring telegraphs, pay for an inferior telegraph 125*l.* a mile, instead of 50*l.* a mile—is that it? I think it likely they would do so, but there are other considerations if you would allow me to explain.

By all means.—In laying down the telegraph it is most likely that those who require it would go to a company who had such powers to lay it down at once; that is, the railway company would go to the company that had the power to lay it down in the streets, instead of going first, for instance, to myself, and then having to go

to the Company afterwards to get their sanction, or to employ them to open the streets to complete it.

But, supposing the Company, and nobody else, had the power of opening the streets, how should you do then? Certainly, to open the streets would be the best plan, but other plans could be used.

What are these other plans? For instance, if the wire could be suspended to the wall of houses, cast-iron brackets could be fixed in the wall to support the wire.

With the leave of the owner of the wall? With the leave of the owner of the wall, it is true; but still cast-iron brackets could be used and wire put on them in the wall. Another plan would be to put up posts at the side of each lamp-post, without interfering with the traffic of the town.

You are lawyer enough to know, I suppose, that none of those plans can be adopted without the aid of Parliament, or the consent of each individual owner? If they are carried along the lamp-posts of the street, perhaps the consent of the town-councils might be sufficient.

Or might not? Or might not.

Well then, you are of opinion, that some mode of enabling the person who lays down the telegraph to carry it through the town against all opposition is exceedingly important, are you not? Repeat the question.

You are aware of this, are you not, that some mode of enabling the person who lays down a telegraph to carry it through a town against any opposition is of exceeding importance for the perfection of the telegraph? It would be of importance for the perfection of the telegraph, I have no doubt.

Is it not of very great public importance, that this telegraph should be perfected—either yours, or Mr. Wheatstone's, or any body else's plan? Yes.

By the Committee.

Have you any proposition made to you for the purchase of your patent? No; there was some communication with my solicitor, Mr. Van Sandau, I understood, from Mr. Wilson, Messrs. Cooke and Wheatstone's solicitor, but it was so vague that I do not know what it was.

You have not had any proposition from any other parties? No, I have not.

You say 50*l.* a mile was the cost of the Edinburgh and Glasgow line with one wire? Yes.

If three wires were used, what would it have been? 20*l.* or 25*l.* a mile more for each wire.

By Mr. Hill.

Suppose they had a telegraph in which the circuit was made by two wires; would it not be very easy to make that into two tele-

graphs, according to the plan of making the earth half a circuit? There would be no difficulty about it.

It might be done in ten minutes? Not so short as that.

Half an hour? It would depend on the arrangement of the instrument that might be fixed upon it.

It is only letting down the plates from each wire, instead of from both wires, into the ground? Exactly, and attaching some metallic surface, or carbon, to conduct the current into the earth.

If you were well paid you could do it in an hour? I should want more than that.

Two hours? More than that.

Well, three? I should like a day.

By the Committee.

Is the telegraph complete between Edinburgh and Glasgow? It is complete so far as the whole line is concerned; the intermediate stations are not yet complete.

You mean to say it would only cost 50*l.* a mile to complete it for working purposes? To complete it entirely: there is no other expense, except the instrument at each station.

That has been working three months? It has been working, seven miles, since July last. On that line, seven miles were complete in July, from Edinburgh to Ratho.

Perhaps you know the expense of Messrs. Cooke and Wheatstone's? I do not. I heard it stated, on Friday, at 125*l.* a mile: I think I understood so.

That was the mean cost? Yes, the mean.

Have you made any offers to any railway companies in England, to lay down telegraphs at the rate of 50*l.* a mile? I made an offer to the Midland Counties Railway.

When? I think it was in December; I am not certain.

Had you any answer? I got an answer, but I did not get the contract.

What was the answer? I do not remember at this moment. Several letters passed between Mr. Barlow, the managing engineer, and myself; but I think I did not get an answer to my estimate—I think not. For some time afterwards I had occasion to come to London, and I called on Mr. Barlow, and was surprised to see the instrument which you see there, with the needle, in his office. He told me that Mr. Cooke had got the contract; and I told him then that that instrument was on the principle of my single wire and single index telegraph. He said he had nothing to do with that.

Have you applied to any other company? No, that is all.

By Mr. Hill.

When was it you obtained that answer? Which answer?

The one you have just mentioned from Mr. Barlow? It was in the beginning of the year.

January? Yes.

(*Adjourned.*)

MARTIS, 24o DIE MARTII, 1846.

(CAPTAIN BOLDERO IN THE CHAIR.)

Cross-examination by Mr Hindmarsh continued.

Did you not make some application to the South-Eastern Railway Company respecting the erection of a telegraph? No.

Or some offer? No.

None whatever? No.

Was there no negotiation or communication whatever between you and the South-Eastern Company? No.

Or any of the servants or officers of the railway? I called once at a station on a gentleman connected with the Croydon Railway. I called once and that was all.

And that was respecting the erection of a telegraph, was it not? Yes, it was.

Who was that, Mr. Barlow, was it not? I don't think it was, I don't recollect the gentleman's name.

Was it Gregory? No, it was not.

However, you did call on some one? Yes, I did.

And did you state to him the terms on which you would erect a telegraph? I don't remember the conversation, it is a long time ago—a considerable time ago.

A long time? Yes, before I went down to Scotland.

How long ago is that? More than twelve months.

I want to know the kind of posts that you have erected upon your Scotch telegraph? The posts I have erected are what are termed Norwegian spars. They are used in London for scaffolding.

Common scaffolding spars? Yes.

Round spars? Yes, which I consider to be the best.

And they are also the cheapest, I believe? They are cheapest also.

They come to a very small sum of money? They do not come to a very large sum of money, but I decidedly consider them to be the best.

I believe some shilling or two each, independent of the labour, is the outside cost? More than that.

Not much, some two or three shillings each? It hardly amounts to three shillings.

It does not amount to three shillings? No.

I believe you have seen the Great Western Railway telegraph, have you not? I have.

The posts erected there are somewhat similar to yours? They are not.

Are they a more expensive description? I should think they were, but they are such posts as I would not use in preference to the Norwegian spars.

You have only one wire on your Scotch telegraph, and that, I believe, is placed at the top of the pole? It is.

What is the cost of each of your indicating instruments, or whatever you call it, which you place at each station ? Twelve pounds.

How many stations have you on the Edinburgh and Glasgow Railway for your telegraph? Nine, including seven intermediate stations between the termini.

When you communicate intelligence from either of the termini, does the apparatus at the intermediate stations also communicate like signals? Yes, they do.

Now having one wire only, if there was any accident to happen to any part of the line, of course, until that was repaired you could not go on? I consider that if any accident happened to one wire, it would happen to two, three, or four, equally the same.

You mean to each of the other wires? Yes.

But still if there was an accident to happen, as a matter of course you could not go on till that was rectified? Certainly not.

Now whilst you are making communications between the two termini of your telegraph, if you have only one wire you cannot make communications between the intermediate stations at the same time? If the intelligence is intended to be delivered between the intermediate stations, there are first signals given to say that the intelligence is from one particular station to another particular station. Signals are, in the first place, given for that purpose.

You don't understand my question. I have not put it clearly. I should be glad to explain this.

I am quite sure you will. Suppose communications of intelligence are going on between Glasgow and Edinburgh along the entire line, and you want to make communications between any of the intermediate stations, can you do that while the communication is going on along the whole line? You cannot send two communications through the same wire at the same time.

Then if you want the power of having double means of communicating intelligence at the same time you must have more wires than one? Yes, certainly.

I think I caught, but I was not quite sure, yesterday, that the most improved instrument which you say you have invented, cost somewhere about 60*l*. Is that true? Yes, something near that sum.

Is that the instrument which you say is comprised in your last patent about to be specified? I mean the instrument not the wire —the mere signal instrument.

Then it would be necessary if you use that instrument at all, to place that instrument at each of the termini, and also at each intermediate station where that was to be used? That instrument would be more particularly employed in its fullest extent, if the whole language is put into it (as I mentioned yesterday,) between two towns or two places where a great deal of communication is necessary; but for railway purposes, for the purpose of transmitting intel-

ligence from station to station, I should, instead of taking it in its full extent, put all the intelligence necessary into one table.

My question is this—if you use this improved instrument of yours at all, you must have one at each terminus and at each station? Yes, certainly.

An instrument costing 60*l.* to 70*l.* I think you said? Yes, but I consider that it is not necessary to use that instrument for railway purposes.

But for the purpose of a general telegraph it would be necessary, in your judgment? Yes, to have the best telegraph.

I hardly need ask you whether it is possible to construct a telegraph at 50*l.* a mile with an instrument of that description? Certainly at 50*l.* a mile—it has nothing to do with the wire—the wire is a different thing.

The 50*l.* a mile was for the conducting wire only and the supporters? Yes.

It has nothing to do with the indicating instrument? No; these indicating instruments on the Edinburgh and Glasgow Railway cost 12*l.* each.

You say that you made a considerable profit out of your 50*l.* I suppose you would make somewhere about 20*l.* a mile, did you not? I do not think it is for me to say the profit I made exactly. I made a profit, and a profit that I am contented with.

Your mode of insulation, I believe, is asphalt placed in iron caps at the top of your pole? That is one mode.

Is that the mode you have adopted? Yes; asphalt and wood on this one.

What sort of wire do you make use of? Iron wire.

Galvanised? Yes.

How thick? The thickness known by No. 9.

About three-sixteenths, is it? Yes; I think rather more.

Re-examined by Mr. Webster.

This which you have spoken of as the more expensive instrument, that is to have the whole of the language in it, as I understand, was the sort of instrument that would be used as between London and Portsmouth or London and Dublin? Just so.

But that it is wholly unnecessary to have so expensive an instrument for railway purposes? Yes.

The signals are limited? Yes.

The I and V would answer for that purpose? Yes; I have arranged a table for railway signals with 190 squares in it, and the I and V is so arranged at the top and the side that I can transmit sentences by the I and V. I have arranged that for railway purposes and it answers extremely well.

What is the cost of that? Twelve pounds.

That is the ordinary instrument? Yes.

My friend has asked some questions about the cost, and so on.

I understood you to say yesterday you should be most happy to take any contract for 50*l.* a mile, being paid as you went on? Yes, I should be glad; I should make a good profit, at least a profit I am contented with.

Now as to this distinct telegraph, you say you cannot send two communications through the same wire at the same time, but that you can send a communication from end to end of one wire, and also to the intermediate stations at the same time? Yes.

How is that done? There is one wire from end to end. I cut the wire at each of the intermediate stations, and take the two ends into the station. I attach the ends to the telegraph instrument so that the electric current, when it passes at all, has to pass through all the instruments on the line, and works them all alike. If I move the handle of any one instrument it affects the pointers of all, so that the same signals are given at all the stations at the same instant.

There could not be two communications along the same wire at the same time, but you can send a communication from end to end and to each intermediate station at the same instant? Yes.

And the velocity of transmission is so great that it appears to be instantaneous? Yes.

Now may that be described as taking off a portion of the current, diverting it, and then returning it again to the main wire? That is a plan I adopted for the electric clocks.

May this mode be described in this way, as taking off a portion of the current and then diverting it again into the main wire? Yes.

Was that a discovery of your own? I believe it to be so.

Is it a very important discovery? It is for electric clocks but I do not think it is for telegraphs.

You say you believe it to be your own? I do.

Did you borrow it from any one else? No.

If it existed before, it was without your knowledge? Yes, it might exist before as a scientific fact, but I have never seen it applied at all to any useful purpose.

You did not know of it having existed as a scientific fact? I did not.

You discovered it yourself as a scientific fact, and also applied it? I did.

Whether it existed before or not you do not know? No.

As I understand you, before the applications you have last referred to, it was perfectly well known that electricity would pass from one end to the other end of a wire? Yes.

Did you discover that in addition to passing from one end to the other of a wire, you could take off or divert a portion of the current and return it into the wire again? Yes.

By the Committee.

The whole portion of the current you take off? Only a part.

You never heard of that before ? No.

Not in the course of your investigation ? No.

Did you ever read any book on electricity or magnetism ? I have read a good deal.

You never heard that any portion of an electric current could be diverted and returned again into the same wire? No, not to make it useful.

That is not the point, I am speaking of the discovery, leave the application alone—you never heard of it ? No.

I believe Mr. Cooper stated the same thing the other day ? I don't remember. I should be happy to explain that, for it does not seem to be properly understood. It has been well known, that if two wires are used instead of one, that a portion of the current would pass through both; suppose two long telegraph wires are used instead of one, and allow the current to pass through both, if they are of equal length and equal thickness, an equal share would pass through each. But take a portion of one wire, say the wire was a mile long, and that on any two yards of that wire you tie a wire there, and then from two yards of it tie the other end of it; it is not so evident, at least it was not to me, that a portion of the current would pass through the small wire; it is that which I mean applying; it is that I use for the purpose of working clocks. But if a wire was carried throughout a town, for instance, to work electric clocks, and that wire had to be broken, as I break the telegraph wire for the telegraph stations—if it had to be broken in passing to every house, and injured in any one house, then the accident would stop all the other clocks. It occurred to me it would be useful if the main wire were left whole and a derivative current let into every house without breaking the main wire. It was in that way I considered it a discovery. I tried it and found it would answer, and it is contained in the patent of 1843.

By Mr. Webster.

That, I believe, would represent what you mean (handing a diagram to the witness) ? Yes.

Did you ever before your discovery or since your discovery, see that contained in any published book ? No, I did not.

Not since your attention has been directed to it ? I have never seen this published at all in any manner.

Did you publish it in your specification as a new thing. I did.

Do you know it is published in a subsequent specification of Cooke and Wheatstone's as a new thing? Yes.

In a patent subsequent to yours? Yes.

Mr. Hindmarsh—My friend had better point out where we have done so.

By Mr. Webster.

An honourable member asked you whether you had made any offers to railway companies to lay down your telegraph at 50*l.* a mile

—have you offered it to railway companies, and advertised it in papers to the extent of your powers? Yes, I have.

I believe, with the exception of the contract on the Edinburgh and Glasgow Railway, you have been unable to obtain any contract? I have obtained none other.

Had you considerable difficulty in getting that contract? Yes.

Were the directors generally very much prepossessed with what they had heard or knew of the invention of Cooke and Wheatstone? They were.

Were you obliged to institute several experiments to satisfy the chairman of the superiority of yours? Yes.

And was it owing to that that you obtained the contract? I consider so.

You were also asked by an honourable member of the Committee whether you had had any proposition made to you from any parties respecting the purchase of your patent? Yes.

I think your answer was that you had? It was.

I believe there was a proposition to Mr. Van Sandau, your attorney? Yes.

But you had at some time or other some conversation with some gentlemen upon it? Yes, it was mere conversation.

State the purport of that? There was some conversation between myself and two other gentlemen.

It did not amount to a proposition? Not at all.

What you did refer to passed between Mr. Wilson, the attorney for the promoters, and Mr. Van Sandau? Yes, what I referred to yesterday.

Now you were asked by Mr. Hill whether you were not aware of Messrs. Cooke and Wheatstone's having used a single wire with the earth for completing a circuit for a long while before your patent? I believe I was asked that question.

When were you first aware of their having used it, or of their having laid any claim to it? It was a very considerable time after my specification of 1843 was enrolled.

Was it from seeing their specification of their last patent? I believe it was.

Was that the first time you were aware of it? I think it was—I believe it was; no, I remember, it was at a meeting of the Society of Arts in the Adelphi: it was there, I think.

Was it after the date of its being published in the specification of your own patent? A very considerable time.

You mentioned the advantage of the single wire and the circuit of the earth. I think you said there was the saving of the wire, and there was less power required in passing the electricity? Two advantages—a saving of the wire, and a given power of electricity would work at a greater distance than it would with a double wire; a much greater distance.

Is the use of the metallic circuit a peculiar disadvantage as regards the quantity of power? It is.

With respect to long distances for instance? I think it will become more obvious when telegraphs are extended and the distances will be longer than they are now.

You think for telegraphs of one hundred miles the metallic circuit could be employed? For one hundred it might, or perhaps two hundred, but it is evident to my mind, from the investigations I have made, and the experience I have had, that whenever the limit comes to the transmission of electric currents through wires, it will appear much sooner on a metallic circuit than what it will on a circuit composed of earth and wire.

I believe you expressed that in this way; you say that the resistance to the motion or power required to produce it is incomparably less in the earth than in the wire? Yes; I don't think the earth offers any resistance, if there is a sufficient quantity of conducting surface to the ends of the wire. I don't think the earth offers any resistance, whereas the wire does.

The wire offers sensible resistance. If there is sufficient surface you think the resistance of the earth within the distance is insensible? Yes.

You were asked some questions by my friend, as to having been at the Great Western Railway and the Blackwall Railway; did you knowingly, in point of fact, borrow any thing, at any time, from the inventions of Cooke and Wheatstone? Never.

Did you learn any thing respecting this invention from Wheatstone, at the interview you have spoken to? Never.

You were asked some questions, by my friend, respecting this telegraph on the Edinburgh and Glasgow Railway, and the substitution of the needle, or of the circle: is the mode that you use there for the needle a different thing from any thing used by Cooke and Wheatstone? It is new altogether: it is different in application from the deflecting needle of Oersted. My plan of deflecting, or making the electricity act on the magnet, is very different in arrangement from the deflecting needle of Oersted.

When was the needle of Oersted published to the world? I believe in 1819.

Was it made the subject of a paper by Dr. Richie, Sir Humphrey Davy, and many others, before 1830? Yes.

And by Monsieur Ampêre? Yes, I believe M. Ampêre suggested it for telegraphic purposes.

Was it published by Alexander, in Scotland, and lectured on by Mr. Davy in this city, in 1837? I have seen it recorded so.

Now, my friend asked you about an invention for moving the coil for giving the signal; that is valuable for slow motion and for application to clocks, but not so valuable for telegraphic purposes? For telegraphic purposes you want quicker action. It would not do,

in the pendulum of a clock, to put a magnet at all, because the magnet would attract iron, or any thing of that kind, in the neighbourhood: therefore, I put the copper wire in the pendulum, and make the magnets fixtures, so that for clocks it is valuable.

My friend also asked you a question respecting your not having used the asphalt on the Edinburgh and Glasgow Railway; what is the reason? The principal reason was that the directors would not permit the railway to be opened.

I believe in new railways, when there is a new embankment, there is considerable subsidence? Yes, there is.

So that it would render the opening of an embankment a serious thing? There is an objection to it on a railway newly made, because the embankments do not subside equally.

Is that mechanical or engineering objection the only objection to using asphalt? It is.

Is it a cheap mode of doing it? It is—I consider it so.

My friend has asked you some questions about the use of these posts: the use of the posts was mentioned in that paper of Steinheil's that General Pasley referred to, and in this relation of Mr. Sturgeon, published in 1839? The uses, and some modes of applying the posts, are set forth there.

In the manner of Steinheil, many years ago? Yes.

I believe that passage describes it (pointing out a passage in a pamphlet to the witness)? Yes.

By the Committee.

You stated that your system of communication between Edinburgh and Glasgow is altogether different to that of the Great Western? Yes, excepting that posts are used in both.

You have one wire instead of five? Yes.

And the machines at each end are different? I am not aware that in Messrs. Cooke and Wheatstone's telegraph they have put up any apparatus at intermediate stations, such as I have done.

Would you propose to put up a telegraph with one wire on a line having the traffic of the Great Western Railway? Yes.

You would put up only one wire? Yes, for the traffic of the line alone.

I am speaking of all the purposes of or which a telegraph is to be applied? I think with the arrangement of my new instrument one wire would be quite enough.

For all purposes? whether railway purposes or otherwise? Yes.

And you would advise that? I would advise that certainly in the first instance. Another wire could be put up at any time on the same posts.

Would you advise that with reference to expense, and what would be the expense? The expense would be the same as I have stated, 50*l.* a mile.

That is the wire, exclusive of the instruments at stations? Yes, exclusive of the mere signal instruments at stations.

And for the traffic of a line like the Great Western, seeing that the telegraph might be used for all purposes, you think one wire would be sufficient? Yes.

Do you think it would be sufficient in the event of an accident to that one wire? I consider that if an accident happens to one it is sure to happen to the rest at the same time.

How? Because it must be by some injury.

Are they not placed one above another? They are, but I do not know of any thing that would come in contact with one wire that would injure it that would not injure the rest.

Do you think it impossible that the lower wire should be struck without the other four above it being struck also? I do not think it impossible, but I think it improbable.

Why is it improbable? A stone or a piece of iron falling off a carriage might strike the lower wire without injuring the others? I do not think a stone or a piece of iron would break either of the wires.

What accident, then, do you contemplate? Such as the train running off the line.

That you think would be fatal whether to one or five? Yes.

Have you ever heard of an accident of that kind happening? I heard of one on the Great Western Railway—I did not see it.

Did it break one or all? I understood it broke all.

By Mr. Webster.

Running against a post, for instance, would break them all? It would take them all to the ground, it might or might not break them.

By the Committee.

You say you have advertised your telegraphs at 50*l.* a mile? Yes.

Have you had any applications from companies? No, I have not in consequence of the advertisements, that I am aware of. It was through an advertisement that the Edinburgh and Glasgow Railway directors had their attention first drawn to it.

The use of the telegraph on that line you think arose from your advertisement? I think so.

Was it advertised in the English papers as well as the Scotch? It was advertised in the *Railway Times*, the *Railway Record*, and the Scotch papers.

Have you had applications from English railway companies? There is one application just now that is in negotiation for a short line.

From a railway company? Yes.

For a short line? A short telegraph.

It is for a short line? Under a tunnel.

You have not had an offer for laying down a telegraph where the expense would be the greatest. The longer the line the greater the expense of laying down the wires? I have no offer of that kind.

Will you tell me when you inserted this advertisement in the newspapers in England? They have been inserted these last nine months I think; I have revoked them—I mean to alter the advertisements—they have not appeared for these last six weeks or two months.

When was the experiment at Nine Elms? In 1844.

Have you advertised since that? Yes, it was since that I did advertise; I never advertised before.

But the experiment at Nine Elms was not altogether successful, was it? I considered it successful as a mere experiment, because I had no idea that it was to be considered any thing but a mere experiment to see whether the printing telegraphs, that is the machines themselves, would work or not. It was never told me at the time, nor till a little time afterwards, that it was going to be compared with a complete telegraph at all. I was obliged, at that experiment, to do it at my own expense entirely. I could not afford much, and instead of setting up poles or laying down asphalt to insulate the wires properly, I got permission to take the use of an old paling to set the wire on. I used that. There was no other insulation used, except a bit of leather to keep the rain off. Therefore the insulation was not perfect.

Tell me exactly the object of that experiment as you understood it. The object of the experiment was to show the instrument working. That was my object. The object of my friends was to get the Admiralty contract.

Do I understand you that your single object in that experiment was to see whether you could print with certainty and rapidity by means of electrical arrangements? Yes, by means of electric currents derived from the earth.

That was your sole object? No, my principal object.

What other? We were in correspondence with the Admiralty with a view of laying it down between London and Portsmouth.

But not for printing? Yes, printing.

Printing solely? Yes.

Will you be clear with me? I want to know from you distinctly what object you had in view in trying the experiment at Nine Elms. Was it, first of all, with this object, namely, to show that you could print by electrical arrangements? Was it for another object, to show that you could convey telegraphic signals with certainty and rapidity, that is to say, for the ordinary purposes of the electric telegraph your plan could succeed? It is rather a difficult question for me, because a friend of mine, Lieutenant Wright, was the principal person that first negotiated with the Admiralty. What passed between him and the Lords of the Admiralty I do not know.

I want to know from you what your object was as a man of

science? My object was to show a printing telegraph worked by currents derived from the earth.

What was your second object? The second was, together with Lieutenant Wright, to see if we could get the Admiralty contract.

By showing that your experiments were successful? Certainly.

Were they successful for that purpose? To my mind they were.

Nay, nay; were they successful? Did they convey the signals in less time than other telegraphs would convey them, or in what way did you make out your success to your own satisfaction? I will tell you. All other telegraphs that were in action were signal telegraphs. I considered it a very great improvement if a correct printing telegraph could be made.

Leave alone the printing; keep them distinct. I am endeavouring to do so. In the signal telegraph the recipient of the message marks down every letter sent by the telegraph. Therefore if there is any mistake, the recipient of the message may say he marked it down as the telegraph presented it, and it would not be known at which end of the line the mistake occurred. Therefore, to get over that difficulty, I endeavoured to make a printing telegraph that would mark down its own signals; and to do that it was necessary to make an arrangement whereby the instrument would from one end send to parties at the other end intelligence whether it was working right or not. There was no other telegraph that would do that before. In signal telegraphs it was the recipient of the message that always put down the signal, but a printing telegraph is for a different purpose. Therefore it is necessary the instrument should give it even if no one might be there to receive the message. I accomplished that object. I made an arrangement whereby the telegraph sent back notice to the transmitter of the message whether it was working rightly or not. I also applied the currents of the earth to it—a scientific fact I had discovered—and I was anxious to see how far it would work, and I tried it as far as my means would permit me. It was for this object and not as an experiment for the contract of the Admiralty, that I was interested in it, but Lieutenant Wright, and, of course, myself were eager to get the contract for laying it down.

Do I understand, then, that you had three objects in view? First, to show that your printing telegraph would work and return information to the party working it that it was working; next, that you had a telegraph which could send signals of an ordinary kind, and thirdly, that you wanted to get the contract with the Admiralty? The object of sending ordinary signals I had not so much in contemplation, but the rest I had.

That is the point; then for the purpose of transmitting signals, you did not make experiments at Nine Elms? I made a few experiments with the I and V telegraph.

For that purpose? Yes, after I had done with the experiments on the printing telegraph, I tried several with the I and V.

Were they successful? Yes.

Tell me in what you consider they were successful? The signals were transmitted correctly.

And returned correctly? And returned correctly.

And in what time? In less time than the printing telegraph. I cannot say the exact time.

I want the actual time, to compare your experiments with ours? I did not bring that invention forward at all equal with the printing telegraph; it was not so matured at that time.

Keep from the printing telegraph; what I want to know from you, as a gentleman is, whether your experiments made then for the purpose of transmitting signals in the ordinary way, were successful or not, and if so, in what the success consisted? I consider the success consisted in transmitting intelligence backwards and forwards with sufficient quickness, when compared with the means I was obliged to employ.

With sufficient quickness? Yes.

What quickness—what do you consider to be quickness? I must be allowed to think a little.

As much as you please. I should say by the I and V telegraph—I had not complete instruments there—but I think I could send about twelve letters of the alphabet per minute.

Will you reduce your answer to a practical shape; in what time could you send a signal to Wimbledon and back, or in point of fact, what time did you send a message to Wimbledon and back? I should like to make a reference to the number of letters.

Tell me the shortest time that was occupied from the time that you first made the signal till the time the answer was returned to you; let it be the shortest signal you like? Within a minute.

That you are prepared to state? Yes.

That was done more than once? Yes, with the I and V telegraph.

Now take a message involving four-and-twenty letters? Two minutes.

Did you happen to see a yellow bit of paper that was handed about here yesterday? I did.

Did you see the time mentioned as occupied was six minutes and so many seconds? I saw the memorandum, I don't know what it was.

You know nothing of it? No, that was printed by the printing telegraph.

That occupied some minutes? Yes, six minutes I am told and some seconds.

I understand you to say, you sent signals to and from Wimbledon in a minute? Yes, by the I and V telegraph.

Were any of the Directors of the Company present? I don't know that they were, because it was after the experiments with the printing telegraph.

Did any body present make any remark to the Directors? Not on the I and V telegraph, that I am aware of.

But in any respect relating to those experiments? Not that I am aware of.

Were the experiments tried then, with no view of introducing your patent on the line of railway? The Lords of the Admiralty called themselves, several of them.

Was any report made to them, or did they make any report? I never saw any report; I understood that General Pasley made a report, and I heard General Pasley say, that Captain Brandreth and Mr. Farraday did.

Was Mr. Farraday present? Yes, he saw the experiments twice.

Would he attend here to give us an account of them? I dare say he would.

Can you tell me whether or not any report was made to the Directors, and whether the Directors subsequently have made application to you to lay down your wires? I never heard of it.

But if your telegraph can be laid down at 50*l.* per mile, how did it happen that the Company has purchased one three times your cost, is there no explanation of that? I cannot give any explanation of it, it is quite unknown to me.

Then you think that your experiments were successful, and that you have no doubt that you could lay down your wires at 50*l.* a mile? No doubt of it.

And yet you have the fact that the Company preferred another telegraph at 150*l.* per mile? I don't know what it is.

Have you not heard? It was said 125*l.*

That is the mean between 100*l.* and 150*l.*; but those facts are known to you? Yes.

And you cannot furnish the Committee with any explanation of them? The explanation that is before my own mind would not, perhaps, be suitable. My own conviction is this:—the experiments that were undertaken with limited means, of course could not be effected so as to compete with a telegraph that was put up and was long in action before: there had been time to mature it; time to work it; time to learn the men to work it correctly; time to give them practice; and time to work it expertly; and that, too, along a line of twenty miles, on the Great Western Railway. When mine had to compete with that, it is not so very difficult to imagine the reason. But there is another reason. It was put out by Professor Wheatstone, as I am given to understand, that I was a working mechanic in his employment; and that has gone through the whole scientific society of this country. Now, I deny it: I was not—I never was—in Mr. Wheatstone's employment. That had had an influence with the public.

By Mr. Webster.

Have you not certain means of knowing what the feelings of men are, very lately, from an interview you had with Mr. Mouat? Yes, I had an interview with Mr. Mouat.

By the Committee.

What Mr. Mouat? He is connected with railways.

Is he connected with the London and York Railway? I believe so.

In point of fact, you never were in Mr. Wheatstone's employment as a journeyman? Never for a moment.

You had never seen him previously to the 1st of August, 1840? No; that was the first time.

By Mr. Webster.

You never heard of him before you were recommended to go to him by Mr. Baddeley? I never heard of him before that time.

By the Committee.

If you were called on to establish a telegraph communication along a line of railway, which would you adopt, the I and V, or the printing telegraph? I would use for railway purposes the I and V telegraph.

And do you consider you could send messages with as great rapidity by the I and V, as is now done by Messrs. Cooke and Wheatstone's? Certainly, if not greater.

Have you drawn up any regular report yourself of these experiments at Nine Elms? I have not.

Not for the purpose of showing their success? No, I have not.

You have not made their success the foundation of an application to any company, have you? No; because the experiment there of my invention was compared, directly it was shown by me, with Cooke and Wheatstone's that was in action for so long a time before. When it was compared with that, a report from me would have been of no use, because it was so very experimental.

Have you any means of stating to the Committee, in point of fact, the time required for sending your signal from Edinburgh to Glasgow, or the intermediate distance, specifying the several numbers that are required—eight, ten, or twelve—for spelling words, or for vocabulary signals? I have made arrangements for spelling words, and vocabulary signals.

State the time? By the latest experiment in the I and V telegraph, I can transmit from twenty-seven to thirty letters of the alphabet in a minute.

And that is the working condition of this instrument now upon that line? Yes.

And has there been no interruption from any accident during the time it has been at work? No.

No failure? No; I have been obliged to stop the telegraph at the extreme ends when I was setting up an instrument in the centre. They are not all filled in yet.

Is there one at Kirkintilloch? Yes, another at Ratho, and another at Castle Carey, and so on.

Are you aware of any circumstance to which you attribute, or may explain, the circumstance of your not having had any offers in reply to your advertisement? To my mind it is these rumours that have been spread abroad.

And not through any sense entertained by the public, either the scientific part or any other, of any imperfection in your system? Certainly not.

Mr. Hill, in his very able speech, stated, I think, that if an accident occurred to a train passing between station and station, if it either came to a dead stop, or that its speed was diminished, the guard would be provided with an apparatus, might leave the train and apply to the line and communicate with the station in advance of him, or the one in the rear, do you think that practicable? I think it is; I consider that practicable, and as far as I know it belongs to these gentlemen.

That would effectually prevent collisions? It would help.

And would help to save life and property? Yes.

And you consider that this Bill, enabling capitalists to buy Cooke and Wheatstone's patent, will be prejudicial to you? I do.

Do you think that your own scheme could be carried out in a very large and comprehensive way without the aid of Parliament? I think so.

How would you propose, in the event of opening streets being necessary, to communicate between a station and different parts of the town; how would you propose to effect that without the aid of Parliament? The only way that I could imagine is to get the permission of the authorities of the town to put up the wire on cast-iron pillars, such as the lamp-posts, but much higher, sufficiently high to allow all vehicles to pass under it without danger.

That would be a voluntary act on their part, depending upon the consent of the municipal bodies? Yes.

But, in the event of its being thought important to introduce Electric Telegraph Companies, power must be obtained from Parliament? Yes.

Then, how is a great system of Electric Telegraphs to be carried on? Only in the way I have mentioned.

Suppose they refuse it, then it will not be done? Then an Act of Parliament would be necessary.

What is there to prevent you, with your superior invention and the greater economy of your telegraph, assigning your patents, under the authority of an Act of Parliament, to capitalists? I do not know of any thing to prevent it.

If your invention be what you describe it, and if you can carry out a system of Electric Telegraphs through the country at 50*l.* a mile, instead of 120*l.* or 150*l.*, do you not hold out great induce-

ments to capitalists to take up yours instead of Cooke and Wheatstone's? Yes, but it would take a great deal of time and money to convince the public that they were what I state them to be.

Do you know the time and difficulties that have taken place in introducing Cooke and Wheatstone's inventions? I do not know.

Do you know how many years they have been getting the public even to condescend to notice it? I believe since 1837.

And this is 1846, is it not? Yes, it is.

Why should you be exempt from the difficulties and delays which they have had to encounter—in introducing your invention to the public notice? I commenced shortly after or about the same time, and am not near so far forward as they are.

How does that happen? You are the cheaper, and do you not hold out greater inducements to capitalists? The inventions have not come to the perfection they are now in till lately.

Do you think capitalists will go into two concerns, one involving three times the amount of capital that the other does with equal profits? If the public knew the merits of the case, they would not, I really believe, but the public does not know the merits of the case.

Have you not had opportunity of trying two great experiments, one on the Edinburgh and Glasgow Railway, and the other at Nine Elms? I admit I have a greater chance now; but the one at Nine Elms had not that effect, because it was a temporary experiment.

Even appearing before this Committee and opposing this Bill, may give it greater circulation. Now that you are more known, is there any thing to prevent you going into the market with Cooke and Wheatstone's, and selling your patent, which enables you to construct telegraphs at one-third of the cost that they do? I must have the prejudice removed from the public mind. If I had, then I should have equal advantages.

How can you remove it from the public mind except by experiments? And if the experiment on the Railway between Edinburgh and Glasgow is successful, will not that be a sufficient ground to induce capitalists to take you up? It might. It remains now to appear. It is not known much yet in England.

Would you not think it beneficial, if capitalists were to combine to purchase your patent? I think so.

And would you not think it rather hard, if opposition were to take place from a rival inventor to prevent your having the benefit of the combination of capital in your favour? I do not know that I would. If I applied for advantages that he had not got, I could not find fault with him.

Can you, by your apparatus, effectuate that to which the Chairman alluded, and which you have given credit to the other party for, that in the event of an accident happening, you could send the message backwards and forwards. Can you, by your system, effectuate that, in the event of any accident happening? I give them entire credit for that.

Your apparatus could not do that? I have done nothing to effectuate it as yet.

When did you become acquainted with Mr. Finlaison, and state the circumstances? I do not recollect the exact date, but it was in the Polytechnic Institution, Regent-street, when I was exhibiting my Electric Clock and Printing Telegraph, and Mr. Finlaison called at the Polytechnic Institution upon me, and introduced himself to me as coming from the same part of the country.

Is that Mr. Finlaison the celebrated actuary who is now present? Yes.

Then you have found some friends in London? I have found Mr. Finlaison a very great friend.

Did he state what his object and motive was? It was merely because he came from the same part of the country, he wished to be introduced to me, and he introduced himself.

You have found friends to give you some support and countenance in London? I could not have done what I have done, unless I had found some friends.

Mr. Finlaison's object in seeking your acquaintance, was to take you up, and, in short, in consequence of his impression of your ingenuity, and the value of your discoveries, to support you and to protect you as a deserving man? Yes, I believe so.

You do not contemplate applying for an Act of Parliament to assist you in carrying out your inventions? At the present moment, we hardly are resolved what to do—but if this Act passes, I do not know. We must protect ourselves the best way we can.

Do you consider, upon the whole, the experiments that took place at Nine Elms gave the merits of your system a fair trial? It did not, I think; and it exhausted all my resources; and I could not go on with it.

That was before you became acquainted with Mr. Finlaison? No, after.

But it is in full operation on the railway between Edinburgh and Glasgow? Yes, from end to end.

Where it may be inspected by the public? Yes, at either end.

Why did you consider it was not a fair trial at Nine Elms? The posts that the wire was suspended on were not insulated. They were wet wood, and the electricity passed through from the wire to the ground, by the wet wood—and the wire was also broken every day, and almost every hour of the day. People along the line took it away with them and broke it.

You were quite prepared to take the contract, and could have executed the contract as efficiently, or more efficiently than it is done on that line, at 50*l.* a mile? Yes.

Have you made a positive offer to the South-Western Company to do what Messrs. Cooke and Wheatstone have done for 50*l.* a mile? No, because the South-Western Company have a telegraph of Cooke and Wheatstone's.

Have you made offers to other companies to try the experiment?

I have not, for I have been so engaged with this new patent, and other things, that I have not had time. I have been so engaged with these inventions for the last six months, that I have not had time to seek for orders. I have been confined to the maturing the inventions, and not to getting orders.

Is there any body connected with the Edinburgh and Glasgow line in London ? Mr. Miller, the engineer, is here.

I understand that the telegraph on the Edinburgh and Glasgow Railway is your patent entirely ? Entirely.

That there is nothing that may be called an infringement of any other patent. I do not pronounce any opinion, and do not say it invidiously at all, but nothing that you adopt there has been considered by any one an infringement of any patent ? Nothing that I adopt there is the subject of a patent at all in this country, except my own.

That is your patent exclusively, as contra-distinguished from Cooke and Wheatstone's ? Yes.

By Mr. Hindmarsh.

Were you not allowed to try your experiments on the South-Western Railway as long as you pleased, and did you not do so for seven weeks ? It was so for about seven weeks.

By the Committee.

Did the Directors give you every facility or not? They allowed me to lay it down, but without any expense to them, or interfering with me.

I don't mean with respect to pecuniary interest, but did they give you every facility? Yes, they did.

They did not throw any obstruction in your way? No.

As far as they are concerned they gave you every facility? Yes.

And in your opinion that experiment only failed from your not having funds to carry it out in the manner you could most wish? Yes.

That is the only ground of failure? The only ground.

By Mr. Hindmarsh.

And did you not afterwards make a claim on the Admiralty for the costs of that experiment? I do not think it; at any rate I got nothing.

My question is, whether you did make a claim on the Admiralty? I did not.

You said you had never been to the Great Western Railway? I did not. I have been at the Great Western.

Did you not say you had never inspected any of the tables, or any thing of that sort there; did you ever see that [handing a card to the witness]? I can state I never saw that before.

Mr. Andrew Van Sandau called; examined by Mr. Webster.

Are you the solicitor for the opponent to this Bill, Mr. Bain? I am solicitor for Mr. Bain.

You had some communication with Mr. Wilson, one of the solicitors for the Bill, in January, this year, I think, had you not? I had several communications in January.

State what took place. On the 8th of January Mr. Wilson called on me, to state some error in the Scotch specification, under Messrs. Cooke and Wheatstone's patent. Having explained that to him, he then told me there was another subject upon which he was desirous of communicating; that Mr. Bain (as he said) would probably by that time have become satisfied that his inventions were altogether valueless in England; that he could not possibly get any telegraph on any English line, as Mr. Cooke, who had formed other connexions, had already engaged all the greater lines; but that they considered Mr. Bain a gentleman of ingenuity and honour, who they would rather have with them than against them, and suggested that if Mr. Bain's notions were moderate, that then they would be disposed to purchase his interest, and to give him employment on the railroad. I asked him to make a specific proposition; he said no, he would not make any specific proposition, nor could he have it said he had made any proposition, but they were desirous of feeling the mind of Mr. Bain, and ascertaining how far Mr. Bain would be willing to enter into such an arrangement.

By the Committee.

Was this on January 8th? All this was on January 8th. He said that if Mr. Bain should be disposed to sell his patents at a price somewhere about what those patents cost him, and to take employ under them, they would so arrange that he should not come in collision with Professor Wheatstone, and they would employ him as a Telegraph Engineer, paying him from 300*l.* to 400*l.* a-year, and increasing progressively till it had arrived at a certain amount. I desired that communication to be put into writing, that I might communicate it to Mr. Bain. That was objected to, and I was desired to write to Mr. Bain. I stated that I should communicate with Mr. Finlaison, and I asked that I might be furnished by them with a copy of their specification, and to know what was the particular error that was made, which Mr. Wilson was to consider again. On the 17th of January Mr. Wilson called upon me; he inquired if I had heard from Mr. Bain, and I again desired that he should put his propositions into writing. He declined, and I then told him that I would write a letter to Mr. Bain, specifying what I understood as his suggestions, and would show it to him, and I asked for a copy of the specification. The answer then given was, that the specification was in Scotland, and they could not give me

a copy. I suggested they had their draft, and that from the draft they might furnish me with a copy. I was then told that the draft would probably not be accurate; that alterations might have been made in the engrossment, and that, therefore, they could not furnish me with a correct copy. I asked him to give me the best copy he could furnish; he said he was to see Mr. Cooke and take his instructions upon it. He again called on me the 19th of January, stated that he had communicated with Mr. Cooke, that Mr. Cooke declined to furnish any copy of the specification, and at the same time said that he should decline to see my letter, because he would not have it said that they had made a proposition. All they were desirous of doing was of feeling Mr. Bain's pulse, and ascertaining what he was determined to do in the arrangement. I should state that which I omitted, that on the 8th of January Mr. Wilson said if Mr. Bain's views were immoderate, if, for instance, he required 5000*l.* for his two patents that would be totally out of the question.

By Mr. Webster.

I believe at that time you were not aware of there being a Bill in Parliament? I was not aware till long after the last interview there was a Bill in Parliament, or that there was a Bill contemplated.

You did not learn it from Mr. Wilson? I never learnt from him there was a Bill or a Company in contemplation.

When was the first intimation you received of there being a Bill in Parliament? Not till I saw in the newspapers that it had passed the Standing Orders.

That was the first intimation you had had of it? That was the first intimation I had of it.

Cross-Examined by Mr. Hindmarsh.

This I believe was a confidential communication which was passing between you and Mr. Wilson sitting here? I certainly did not consider it a confidential communication; Mr. Wilson called upon me—made the communication, and all that made it confidential, if that made it confidential, was what I have mentioned—that he stated he could not have it said he had made a proposition, and therefore he would not put it into writing.

And did you not yourself say that any thing that passed in this way, verbally, was to be considered as confidential? Certainly not—with reference to the Bill, I said, I will speak to you as much as you please on the subject of litigation—the Bill was not mentioned—but what I put in writing, that shall be the subject of evidence.

Any thing that passed verbally, did you not say that must be considered confidential? Something of the kind may have been said, but not with reference to this communication, because I was to put it into writing, and communicate with my client.

By the Committee.

Was it not a communication which you professional gentlemen consider to be without prejudice? I certainly consider the communication of the offer was not without prejudice, but I should have considered I was not acting the part of an honest man if I had not stated at the time the communication was made to me, that I would not have it said that I had made an offer.

By Mr. Webster.

I believe Mr. Finlaison is part proprietor of Mr. Bain's patents? What interest Mr. Finlaison has in Mr. Bain's patent, I know not certainly.

Mr. Alfred Deacon called; examined by Mr. Webster.

Are you a mechanist? I am.

An Electro-Mechanist? I am.

Have you been in business as a mechanist for eighteen years? I have.

Are you well acquainted with the specifications of Messrs. Cooke and Wheatstone, and the specification of Mr. Bain? I have examined them both.

Have you been employed by Mr. Bain in examining the specification of his last patent which you have heard described? He brought the drawings to me, and I examined them closely.

You are conversant with the mechanical details of the inventions he spoke to yesterday? Quite so.

Are the objects of that last patent so far as regards the single wire, and the single needle telegraph, the same as those which were contained in the early patents of Mr. Bain. They are not the same, they are modifications of it with very vast improvements.

But simply so far as they relate to the single wire and the earth circuit, they are the same? Yes.

Having regard to the earlier patent you have spoken to, have the general series of inventions throughout the three patents been the same? Yes.

You heard what Mr. Bain said yesterday of the capabilities of the new instrument? Yes.

Do you know the capabilities of that model and of the Edinburgh and Glasgow Telegraph? Yes.

Is that capable of doing every thing that has hitherto been done for telegraphic communication so far as you know? I should think so, and more; it works with less amount of force; its construction is superior to any arrangement of electro-telegraphs that I have seen.

By the Committee.

That is the I and V telegraph? Yes, the model of it is now at the corner of the table.

By Mr. Webster.

Do you know how many separate signals could practically be exhibited in the telegraphs that existed previously to those of Mr. Bain? The separate signals would amount to somewhere about thirty-two, which may be combined: with regard to them I should say, from about twenty to thirty per minute might be recorded.

And you say that Mr. Bain's is superior? It is superior decidedly to any thing I have yet seen.

By the Committee.

When you say the instrument there on the table is superior to every thing, are you well acquainted with all the Electric Telegraphs introduced by Cooke and Wheatstone? I have examined the specification and the drawings of both.

Have you seen them in action? I have not.

Can you speak as to the rapidity with which they convey signals? I saw one in action at the Royal Institution, and I conceived it important on this account, that if the current was very weak at the time, there was very great liability of its losing a signal.

My question is, whether you have seen the telegraphs at the different stations at work? I have not.

Then you are not acquainted practically with what is done at the railways? I can ascertain by a drawing, if I see it, the relative merits, as well as when it is put into practice—I can judge pretty nearly of it.

But you have not seen it in operation? I have not seen it; I saw many defects in the old one, that I do not see in the model before you.

Have you been employed by Mr. Bain to make his drawings? No—I was draftsman to Messrs. Holtzapffel, the great engineers of Charing Cross.

You are only a practical draftsman? I am the manager of the mechanical printing department at Mr. Whiting's, Beaufort House. I have followed up mechanism for many years. I have spent a great deal of time and money in experiments. I have many experiments recorded. It is a subject that has taken my attention for many years, and I am tolerably well acquainted with the subject.

Except so far that you have not investigated the practical working of them? No—I do not take the trouble to do that always. If I see a drawing where the principle is so clear, I don't want to see it work. If the error is in the drawing, it will not be very perfect in practice.

You have not found any thing in practice differ from your previous opinion of it? Very seldom. I am not a person who takes a drawing and makes a model in a moment. I have twenty, thirty, or forty drawings made previous to my model. I may state

I have a calculating machine now under my hands, made from a drawing, without having my mind worried by the drawing afterwards; and every part has been successful—I have not had to alter a single part. I have been called on in many instances to look at drawings. I have drawn many times for the Patent Office, and therefore my experience in those matters is great.

Your experience in drawing is greater than in practice? My practice is also great. I have made the present engraving engine at Beaufort House myself, and I can say it is capable of doing more than any other engine.

What engraving engine? For the prevention of forging bank notes, &c.

Was it similar to the one used at the Excise Office? No—the printing machines are similar, but the engraving machine they have not; ours is the only house in London that has such a machine.

You are acquainted with that at the Excise Office? Yes—they were put there, in fact, by Mr. Whiting.

Mr. John Finlaison called; examined by Mr. Webster.

I believe you are the Government Actuary. I am.

You have been long engaged in the service of Government? Yes—for forty years.

Were you in the Admiralty? I was—seventeen years.

You became acquainted with Mr. Bain, I believe, some years ago? Early in 1842.

What led to that acquaintance? Simply my going in to see his productions at the Polytechnic, and wondering at his printing telegraph and his clock.

I believe at that time Mr. Bain was in very limited circumstances? Very—poor fellow! that he was—very.

I think you assisted him in endeavouring to bring his invention forward? To the utmost of my power, which I am sorry to say is itself limited.

Did you assist as regards experiments on the South-Western Railway? To the amount of 300*l.*, and it cost him 200*l.* more. I heard it asked here whether he had made any claim to the Admiralty. I can assure the Committee from my own knowledge, that he has never made any claim to the Admiralty; and if he had, I should have doubted very much the success of it.

I believe you were present at that experiment? I was, many times; I was also present when General Pasley inspected the engine at work in Mr. Bain's own house; and another scientific friend was also present, Mr. Henry James Brooke, the author of the "Geometry of Solids."

You concur in the evidence of General Pasley with respect to the experiments in Mr. Bain's house? I heard him express the highest estimation of them. It was worked by the currents gene-

rated from the earth—the lead water-pipe in the house being the positive agent, and the coke the negative.

The use of those currents generated from the earth, was new? It was discovered on my grounds in my own presence.

Now, with respect to these experiments at the South-Western—you have heard the account that Mr. Bain has given of them—do you concur in the account he has given? Perfectly—every word is true.

So far as satisfying you as to the capability of working a printing telegraph by currents from the earth, it was satisfactory so far? Perfectly. Sir George Cockburn had it before his eyes as well as me.

Was that the principal object of the experiment? I understood the principal object of that experiment was to get the Admiralty to adopt a printing telegraph. From my own experience in the Admiralty, and no one knows better, it did not appear to me that the rapid transmission of a message, which I took to be mere legerdemain—jugglery—was of any importance in state affairs. It did not appear to me that it was of importance whether a message which would be delivered from the Admiralty to the Commander-in-chief at Plymouth was delivered in ten minutes or half-an-hour; that appeared to me not to be a matter of much importance; but the precision and accuracy of the message I thought was; that it ought not to depend on the observance of a third party whether it was printed at the Admiralty and at Portsmouth or Plymouth in the self-same words. If the officer to whom the orders are transmitted should neglect his duty, there are, by such printing, the means of bringing him to responsibility; but by the simple needle there are no such means. It was, therefore, by my own earnest suggestion to Mr. Bain that he applied himself to the printing engine, which he did make, and which I believe was the admiration of Mr. Farraday. It was by my own earnest advice to him that he applied himself to perfect the printing telegraph rather than the telegraph with rapid motions, which only showed signals, and which signals must be, therefore, derived from the report of another person. It was an unfortunate advice, because it occasioned, I believe, the rejection of his plan.

Do you think it was owing to the confusion there was between the telegraph for transmitting signals merely, and that other for printing purposes, the distinction which Mr. Bain assumed, that his plan was rejected? I think so, distinctly. I have no doubt about it. The two were confused, when they were for very different purposes.

Do you concur with him in this, that the experiment was not directed to the transmission of signals? No, but to print. Another thing was, there was a letter referred to by the learned counsel which I drew up myself, and it was signed by Mr. Bain and sent to the Admiralty about the middle of May, 1844. That letter

is of the utmost importance to Mr. Bain's case, because in that letter Mr. Bain gives the Admiralty the alternative of using the two engines, either of them attached to one and the same wire. The printing engines that conveyed the message would also record it. But then, if the end of the wire were shifted to the other or rapid signal telegraph, this last engine would, for ordinary circumstances, be sufficient for the Admiralty, and it made signals as quickly as human eyes could see them. I know, in consequence of that letter, Captain Brandreth came to Mr. Bain with the letter in his hand, for I saw my own hand-writing on it, and he did inspect not only the printing telegraph, but the telegraph for transmitting rapid signals. I saw him examine it, and I was present, and I do know that the Captain's sight could not see the signals faster than the wheel went round and indicated the letters; but I believe Mr. Bain received no answer to that letter. I further beg to say, that on the 3rd of August, 1843, a letter appeared in print in the Mechanics' Magazine, signed by Mr. Cooke, in which he asserted——

Mr. Hindmarsh.

I object to this; the document must be produced if it is to be given in evidence.

By Mr. Webster.

You have searched for, and been unable to find, the copy of the letter that went to the Admiralty? I cannot find it.

Now, you were giving an account of the South-Western experiments, and you stated the objects accomplished, has Mr. Bain, from that time down to this, so far as you know, been very much devoted to the advancement of communication by means of electricity? Oh! certainly.

Are you aware of the different steps he has made in it? Oh! yes, as far as I am able to judge of mechanical productions, which I am not very conversant with.

Do you know as a fact that Mr. Bain has been unable to introduce his invention in England? Oh dear yes; I know it indeed.

Do you know that very great efforts have been made by yourself and others for that purpose? Every effort in my power has been made to get him on, but without any effect whatever.

Was the name of Professor Wheatstone so great that nobody would listen to any thing that Mr. Bain did? So much so that Mr. Mouat said that none of the railway people would believe an angel out of heaven, if he were to assert that Mr. Wheatstone did not make the best telegraph.

Do you know as a fact that commercial men have not hitherto taken up Mr. Bain? Most assuredly I do know that.

Was this observation that Mr. Mouat made use of with reference to an attempt about to be made to get Mr. Bain taken up? Yes.

And he said that if an angel out of heaven were to say Wheatstone's was not the best telegraph he would not be believed? Yes.

You know that they advertised very expensively, and have done so for many years? Yes.

What do you mean by advertising? They inserted advertisements of the price at which they were ready to lay down telegraphs.

Now, was an attempt made by you to get Mr. Bain's invention brought before the Royal Society, in a paper? Certainly—his discovery of the generation of electric currents from the earth.

You made an attempt to get Mr. Bain's discovery of the generation of electric currents from the earth brought before the society? I did, after taking every means to ascertain from two eminent philosophers that it was perfectly new.

Did you succeed? I had a promise from a very eminent member of the council of the Royal Society, in the first instance, to present it, and afterwards he refused to comply.

You were unable to get it brought forward? Yes.

Has your attention been directed to the probable effect which the Bill, in its present shape, may have on Mr. Bain's interest? I conceive it would be the consummation of that system of depreciation to which he has been subject from the first hour to the last.

Cross-examined by Mr. Hindmarsh.

I think, Mr. Finlaison, you are a part proprietor of some of those patents, are you not? I am not. I hold a verbal expectation of being repaid the heavy advances I have made, and probably, ultimately, of deriving some benefit; but I am no proprietor in the improved patents; and I will not be a proprietor in any thing that will subject me to commercial consequences.

Mr. Bain and you are connected together in some way, I believe? Lately, after the experiments at the South Western, and when I had been acquainted with him two years, he rose so highly in my estimation that I willingly connected him with a member of my family.

He married your sister? No, my sister-in-law. That was two years and more after I became acquainted with him.

By the Committee.

That connexion did not lead to your estimation of him, but that connexion was formed by the high estimation in which you held him? Yes—after his experiments, and after I had assisted him to the best of my power. I was asked whether I was part proprietor of the patent. I wish to explain that point. In the first instance, before the patent I think it was, before the patent of 1843 was sealed, considering that very heavy advances were likely to be made by me, an agreement was entered into between Lieutenant Wright and Mr. Bain, and myself—a mere memorandum—that we should be co-proprietors of that patent. But I must state to you that this

agreement is not at all binding, because there were circumstances attending it that rendered it invalid.

By Mr. Webster.

There is no subsisting agreement? No, none whatever. There is nothing else but that, and that was with respect to the patent of 1843, not this new one, in which I have no interest whatever.

By Mr. Hindmarsh.

Now, with reference to these experiments at Nine Elms, I think you said that you saw them very frequently? When I say very frequently, perhaps three or four times.

They were carried on I believe for seven or eight weeks? I should not have thought so much, because it was a dreadful expense, and his means, and mine too, were quite exhausted. There were a great many men employed, and the construction of the printing-engines was enormously expensive.

You had two? There was one at Wimbledon, and one at Vauxhall.

And one single copper wire? Yes.

By the Committee.

Are the models of those printing engines in the room? No. There was a description of them in the scientific journals of the day. I was told they were very refined specimens of mechanism.

You have referred to them in your pamphlet? I got a friend to describe the mechanical drawings; they are referred to, but that part was written by a friend.

By Mr. Hindmarsh.

You are the author of a book published respecting these inventions? I am; it was a reply to certain attacks of Mr. Wheatstone on Mr. Bain. It was a vindication of Mr. Bain, and not an original effort. Mr. Wheatstone had written certain letters in the "Literary Gazette," greatly disparaging Mr. Bain, and saying he was a workman in his employ. I wrote a book in reply to those, and in vindication of Mr. Bain. The letters themselves are in the appendix to the book.

Have you the letters here? They are in the appendix of the book. I faithfully took the letters from the "Literary Gazette."

With respect to those experiments, you say there were none of them directed to the telegraph? Not the experiments with the printing machine, but the I and V was there.

At Nine Elms? Certainly, and was seen there by Professor Cowper and Mr. Cooper.

Was that seen by General Pasley when he was there? I do not think it was; not the single needle telegraph.

How came you not to let him see that? He was a very short time there, and was greatly dissatisfied at the wire being broke.

Was he not there more than once? I never saw him there but once, and it happened on that day that the people were treading the wire down, as they did every day.

I think you say that Dr. Farraday was there? I saw him.

Did he see the needle telegraph? I think not.

You think not? I am not certain.

Was Captain Brandreth there? Yes, I think he was.

Did you show him your needle telegraph? I had nothing to do with the showing.

Was it exhibited to him? Not that I am aware of.

Mr. Webster then put in a Patent, 8th of January, 1841; a Patent, dated 7th of December, 1841; a Patent, dated 27th of May, 1843; a Patent, dated 25th of September, 1845, with the correspondent Scotch and Irish Patent.

Mr. Webster then said—That, sir, with the letters and documents from the Admiralty, will be the case on the part of the petitioner.

Strangers were then ordered to withdraw.

Counsel and parties were then called in and informed, that the Committee were of opinion that the preamble was proved.

The Clauses of the Bill with amendments were then passed.

Several new Clauses were added.

The Bill was then ordered to be reported to the House with the amendments.

EXPLANATORY NOTES.

Page 2.—*Speech of Mr. Hill.*

The first patent of Messrs. Cooke and Wheatstone was specified on the 12th of December, 1837. It was not, however, practically in operation until July, 1839, when the Directors of the Great Western Railway had wires laid down from Paddington to Drayton, a distance of thirteen miles, at an expense of nearly 300*l.* per mile, viz., 3500*l.*—See the fifth report of the Committee on Railways, No. 474, in the session of 1840, and see especially the evidence of the then secretary of that company, and of Professor Wheatstone, taken by the committee on the 7th of February, 1840. It will be seen by the answer to Quere 317, that this first telegraph could not be worked without six wires. But from Mr. Bain's evidence *ante*, p. 76, it appears that he is well content with the profit to be derived from laying down a far better telegraph at about one-sixth of the above price, having only a single wire to keep in order instead of six.

On the 17th of March, 1839, there appeared in "Sturgeon's Annals of Electricity," a translation of an essay by Professor Steinheil, of Munich, on electric telegraphs, and especially explaining his own improvements on Gauss's Telegraph, by causing the earth to complete the current when only one-half of the wire is insulated. Such an expense as 300*l.* per mile, after the knowledge of Steinheil's operations, would, on the part of Messrs. Cooke and Wheatstone, have been wholly unjustifiable if Sturgeon's publication, of March, 1839, had come to their knowledge in the course of that year. But this subject is resumed in the next note. Long before Steinheil and Gauss, however, namely in 1816, Mr. Francis Ronalds, now living at Hammersmith, had reduced to practice a very ingenious, although somewhat costly, system of Electric Telegraphs, which he submitted to the Admiralty, and afterwards described with diagrams in a little treatise published by Hunter, of St. Paul's Church Yard, in 1823. That publication, as well as some score of other announcements of a similar kind, between 1823 and the 12th of December, 1837, when Messrs. Cooke and Wheatstone first published their system, sufficiently refutes the notion that they were the first to propose Electric Telegraphs in England. An idea that they were also the first to apply magneto-electricity to telegraphic purposes is very generally, though most erroneously, circulated. A piece of soft iron enveloped by a coil of wire, and then made to rotate before the poles of a powerfully fixed magnet, will, by means of this process of rotation, produce a strong electric current in the wire by induction from the magnet. Such a current is termed magneto-electricity. It was applied by Gauss, and improved on by Steinheil, in the year 1837, as may be seen in the paper already referred to in Sturgeon's Annals, but was, nevertheless, patented by Mr. Wheatstone in 1840, and by him specified on the 21st July of that year, without any scruple.

Pages 3, 7, 60.—*Speech of Mr. Hill.*

Mr. Hill's very able speech glances at some passages in the history of this case, which though sufficiently remarkable, are yet, without explanation, not quite intelligible.

In June, 1843, Mr. Finlaison, the Government Actuary, published a vindication of Mr. Bain from certain cruel and unfounded aspersions cast on him by Professor Wheatstone in the "Literary Gazette" of the 18th of June, and the 6th of August, 1842. In this work it was shown—

1. That Mr. Wheatstone had, in the "Literary Gazette," and through many other channels, reported most untruly that Mr. Bain was only a working mechanic, who had been as such in his employ. At p. 101, Mr. Bain is asked by the committee, "In point of fact you never were in Mr. Wheatstone's employment as a journeyman?" To which he answers, "Never for a moment."

2. That in the same letters the professor had asserted an astounding untruth, viz.: that Mr. Bain, while in his employ, was under a written agreement not to mention to any one what he was about: no such employ or agreement having ever taken place.

3. That Mr. Bain had never seen nor heard of Professor Wheatstone until the 1st of August, 1840, when he waited on the professor to ask his assistance in bringing forward his then two matured inventions—one of an electric telegraph which should print the message, another of an electric clock; that on the 18th of August Mr. Bain produced to him two rough models of those inventions, one of which, viz., that for printing, the professor purchased for 5*l.* in hand, with a written promise of 50*l.* more eventually—the other of the clock he advised Mr. Bain to lay aside for a time. That in the meanwhile the professor secretly employed one John Lamb, his workman, to manufacture a clock, the very fac-simile of Mr. Bain's model, and had it ready for exhibition at the first meeting of the Royal Society, on the 26th of November following, where he showed it as his own invention.

4. That in ignorance of any such publication or appropriation of his model, Mr. Bain, by the aid of another person, had indeed applied on the 10th of October, for a patent for those clocks, but as her Majesty's first confinement took place on the 24th of November, the royal sign manual could not be obtained until the end of the year, so that his patent bears date only on the 8th of January, 1841. N.B. The stratagem of prior publication is afterwards turned to account by Mr. Cooke, who claims it as public property, in a letter to the "Mechanic's Magazine," printed on the 5th of August, 1843.

5. That between August and December Mr. Bain was engaged by the professor (the better as it would seem to divert his attention from proceeding with the electric clock) in executing a perfect working model of his own printing telegraph, which he had thus previously sold, and which model he delivered at King's College, as also in executing a working model of a more elaborate one, which Mr. Bain also invented, but which was delivered unfinished to the professor at his desire. Both models, however, were retained by the professor (who never to this day has paid the expense of their construction), but who, having thus attained his end, immediately broke off all communication with Mr. Bain under circumstances of the utmost insult and injustice.

6. That notwithstanding his purchase under a written agreement of Mr. Bain's model of the printing telegraph on the 18th of August, 1840, and his clandestine fabrication of the other model of the electric clock, Professor Wheatstone scruples not in the least to deny under his hand in the "Literary Gazette" as above, that Mr. Bain ever showed him the model of either invention at the date specified. Nay, he boldly claims to be himself the author of those two inventions—adducing evidence which only proves that he had some thoughts of effecting or setting about such things, but not until after Mr. Bain had *actually completed* them, and he menaces Mr. Bain, as he had frequently done before, with a threat of making an example of him in a court of law if he should venture to make any use of his own discoveries.

7. That the wide dissemination of such threats, such unfounded assertions, in detraction of Mr. Bain, and such unscrupulous pretensions to the merit of Mr. Bain's inventions, had rendered the Board of Admiralty, the directors of railways, and other persons who were otherwise well disposed to encourage Mr.

Bain, doubtful whether he really had the right to exercise his calling as an electrical engineer at all. [This doubt is still spread notwithstanding he is now the patentee of seven patents under the Great Seal, each one of which had in succession been opposed by Cooke and Wheatstone.]

8. That Mr. Bain having thus, on the 8th of January, 1841, obtained his patent for clocks, and having, on the 25th of the same month, published in a provincial journal a description of his printing telegraph; having, moreover, exhibited both inventions in public lectures at the Polytechnic Institution during the spring of that year, proceeded to make some most important improvements on the telegraph (including the property of the earth to complete one-half of the voltaic circuit without a return wire), which he tried to secure by Letters Patent on the 9th of September, 1841. On the 7th of July preceding, Mr. Wheatstone had also patented, and deposited with Sir John Campbell, a description of certain improvements in his telegraph, in which, however, there was not one word with reference to printing telegraphs. But the ministry being changed before September, Mr. Wheatstone next, but with very transient success, opposed Mr. Bain in obtaining leave to print messages, before the new attorney-general, Sir Frederick Pollock, on the untrue pretence that printing was within the province of his patent of the 7th of July. Mr. Bain being thus refused permission to perfect his own invention, prayed that the deposit lodged in July previously with Sir John Campbell might be opened. This being done, the imposition on the attorney-general was at once detected, and Mr. Bain's patent for printing was sealed, but not until the 8th of December, a delay of three months.

9. That Messrs. Cooke and Wheatstone on the 7th of January, 1842, in contempt of the foregoing decision, as well as of all legal consequences, nevertheless, now included in their specification of their patent of the 7th of July previously, although it was not in the previous deposit, Mr. Bain's invention of *printing*, but only by complete metallic circuits, they being then manifestly ignorant of the property of the earth itself, and of Mr. Bain's intention to apply it as a substitute for the return wire. In the same month Mr. Cooke published (by Simpkin and Marshall) a book on electric telegraphs, without a hint to imply that he was aware that the earth possessed the property in question, much less that he himself had ever applied that property. Mr. Bain, however, on the 4th of June following, having publicly in Hyde Park shown by experiment this valuable discovery, and claimed it in his specification of the 7th of June, 1842, in perfect ignorance that it had previously been known in Germany, Messrs. Cooke and Wheatstone, equally ignorant of the matter, repeated the same experiment on Waterloo Bridge on or about the 5th of September, and then on the 11th of September, 1842, took out their fifth patent, including now, for the *first time*, this property of the earth, which they specified on the 11th of March, 1843. They have, notwithstanding, ever since given out in many publications, that they had all along used the discovery in question, even as far back as since the year 1839.

10. That in the early part of the year 1841, Messrs. Cooke and Wheatstone had most extensively advertised their electric telegraphs, and in many scientific journals had claimed as their own invention Mr. Bain's printing telegraph and electric clock, on which, as above stated, he was then lecturing at the Polytechnic. They had thereby obtained such influence with the periodical press that Mr. Bain found the utmost difficulty in gaining admission for his claims to the columns of any one journal. At last the "Inventor's Advocate" inserted a letter from him on the 24th of March, 1841, and one or two subsequently. On the 20th of May following, a clerk, as it afterwards appeared, from the office of Mr. Wilson, the solicitor of this bill, proffered on behalf of Mr. Cooke, a series of advertisements to that journal if the correspondence of Mr. Bain, respecting electric clocks were to be thereafter discontinued, and the journal was to commence advertising, as it did in fact in the next number, of the 22nd of May. The high-spirited editor, Mr. Bakewell, however, refused

to comply with the iniquitous stipulation, so that only this one advertisement appeared. This transaction is adverted to by Mr. Cooke himself, who inserts the original correspondence between Mr. Wilson and the editor in the "Railway Times" of the 24th of July, 1843. No one who reads Mr. Cooke's letter can doubt the truth of the charge.

Those are among the most material of the charges set forth in Mr. Finlaison's pamphlet, omitting, for the present, the numerous plagiarisms of other men's inventions, which are therein proved against Mr. Wheatstone. They have now for nearly three years remained unanswered, save by Mr. Cooke's letter in the "Railway Times" as above, and by his other letter of the 5th of August, 1843, before referred to in Article 4, which last contains more than one enormous misrepresentation in disparagement of Mr. Bain. These have already been contradicted, however, and their fallacy manifested by invincible evidence in the correspondence with the Admiralty, the production of which was not insisted on by the committee, notwithstanding Mr. Bain's counsel declared it to be a part of his case.—Vide p. 115.

Some of those charges, with the additional one of their having pirated one or two of his best inventions in their patent of the 5th of May, 1845, as undermentioned, are reiterated in Mr. Bain's petition against the bill. Some were proved, as far as permission was given, by Mr. Bain and Mr. Finlaison, who gave the book in evidence to the committee, and who both courted cross-examination as to its contents. But not a word in reference to the charges was asked.

It is stated by Mr. Hill (foot of p. 3) that Mr. Wheatstone's mind being absorbed in science he was bought out of the concern. He was, therefore, an unobjectionable witness. Now the three witnesses produced by the promoters knew absolutely almost nothing of the history of the case. But Mr. Wheatstone, Mr. Cooke, and Mr. Wilson, his attorney, knew it perfectly from first to last. They were in the committee-room personally present on each of the four days of contest. Why were they not called for the better information of the committee, or at least asked to explain away, if they could, any of the foregoing charges? The obvious inference is, that in the opinion of those who had the best means of knowing, the effect of a cross-examination might be of rather perilous consequences. "Pudet hæc opprobia dici et non potuisse repelli." Mr. Hill's own upright mind, save when misled by his instructions, very naturally suggests (p. 7) that "if the facts in Mr. Bain's petition were true, they would be highly discreditable to those whom he represented," and again, at p. 60, he asks "Is it not rather hard upon the two respectable gentlemen whom I represent that they sit here to have statements made, which, if they were true, would utterly drive them out of society, and justly so, as honest men and gentlemen, when the matter never can be tested by putting witnesses in the box."

But as the honourable committee had offered no interruption to General Pasley when he was doing his utmost to disparage Mr. Bain's capacity as an inventor, it might reasonably be supposed that they would not refuse, at so convenient an opportunity, to permit the parties in question to vindicate their character, if Mr. Hill had only strenuously exerted himself to put them forward.

Mr. Bain and his friends would gladly have acquitted Mr. Cooke of having personally consented to the attempt to tamper with the press, in order to exclude Mr. Bain from any public notice, if he had only said a word to that effect in his letter of the 24th of July in the "Railway Times." But in that letter he states that the attempt so far succeeded, as that the editor of the "Inventor's Advocate," in the hope of obtaining Mr. Cooke's advertisements, did, in fact, after the receipt of Mr. Wilson's letter of the 22nd of May, 1841, insert no more letters from Mr. Bain. Yet, in the same breath, he gives currency to a pretended rumour, which it is impossible he could have believed, if indeed such a rumour ever existed, viz., that it was *said* this same editor was in partnership with Mr. Bain! The two statements are, on the face of the documents, not only unfounded, but manifestly inconsistent with each other.

In his letter of the 3rd of August, 1843, to the "Mechanic's Magazine," Mr. Cooke lays down three propositions in disparagement of Mr. Bain's mode of insulating a telegraphical wire by asphalte, which the non-produced documents at the Admiralty would have most effectually refuted, if they had been made forthcoming.

1st. That the expense of the material itself must have cost nearly 66*l.* per mile.

2nd. That the cost of laying it down, inclusive of this, but exclusive of the wire, could not be less than 150*l.* per mile.

3rd. That, except at very low temperatures, asphalte itself is not an insulator but a conductor of electricity. He adds, that dear-bought experience had induced him to lay aside all thoughts of using asphalte for such a purpose.

Possibly Mr. Cooke, although at that date an electrician of seven years practice, might nevertheless have been ignorant that there exists in this country a material, costing no more than twenty shillings per ton, which is absolutely identical, as Mr. Cooper the eminent chemist proved, with Claridge's asphalte, both in analysis and in every other property; and that when boiling hot, at 320 degrees of Fahrenheit, it was found to be a most perfect *non*-conductor.

It is a sufficient answer to the unscrupulous statement just referred to, that Mr. Bain is willing to lay down his wires in asphalte, at one-half the sum which Mr. Cooke specifies.

The last and most serious grievance which Mr. Bain has to lay to the charge of Mr. Cooke, is the appropriation to himself, with scarcely a colourable difference, in his and Mr. Wheatstone's last patent, specified only in November, 1845, of Mr. Bain's single-wire and single-index telegraph, which was worked before the Committee, and had been patented by Mr. Bain on the 27th of May, 1843. The deviations which are made from Mr. Bain's original plan, are, in truth, only so many imperfections in the imitation. As Mr. Cooke is now using this copy of Mr. Bain's invention on every line which he has recently laid down, it is very difficult to exculpate him from a wilful invasion of another man's property on the score of ignorance. The facts of the case, however, are matter for judicial investigation, and it is not to be lost sight of that these, and all the foregoing charges are sworn to in many affidavits, already on the file of the High Court of Chancery.

Let the impartial reader of this note, now only ask himself whether Mr. Bain, in his competition as an inventor with the promoters of this Bill, has hitherto had fair play, in any quarter; whether he and his friends have not shown the utmost anxiety for publicity, even to the minutest detail; and whether, on the contrary, his opponents have not, in every instance, shown a desire for the most furtive-like concealment, even to the degree of withholding, as witnesses, the men who have practically worked Mr. Cooke's original telegraph, from whom it might have been elicited, as is rumoured, that its imperfections in practice were so numerous, that its service could not have been depended on for a day.

Page 20.

General Pasley says, "The Telegraph established by Messrs. Cooke and Wheatstone, long before my examination and comparison, was infinitely superior to what Mr. Bain's was then. It is possible he may have improved it since. *I don't think he could have improved it without borrowing some of the arrangements of Messrs. Cooke and Wheatstone.*" When a public officer of General Pasley's high rank deposes to such an opinion, his belief must be founded on one or other of two convictions: either that, by some gauge of his own, he had sounded the depth of Mr. Bain's capacity as an inventor, and found him shallow, or else, that in 1844, Messrs. Cooke and Wheatstone had attained the *ne plus ultra* of perfection. But this last is negatived, by their having taken out a patent for further improvements, in May, 1845, in which

the subsequent evidence shows they have appropriated more than one of Mr. Bain's most important inventions—a matter now actually *sub judice*.

Page 21.

General Pasley says very truly, "He stated that unless he (Mr. Bain) communicated between parts of some distance, that it was impossible to form an opinion." This very kind advice, however, involved Mr. Bain and his friends in an expense of 500*l.*, without any other result than that of demonstrating his ability to print by electricity at very distant places.—*See* the EVIDENCE, p. 110.

Page 24 (*last Line*).

When a wire is, by means of asphalte or some other substance, protected from moisture, or so placed as that no moisture shall convey any part of a current of electricity passing along such wire into the earth (which would occasion a dissipation of the fluid), it is said to be "*insulated*." When a metallic pointer revolves on a dial, having radii of wood and metal alternately, if an electric current acts on this dial, the current will flow when the pointer is in contact with the metal, it will *not* flow when the pointer is in contact with the wood. This process of making and breaking the current, as occasion requires, General Pasley deems to be the *insulation* of a wire!—*See* his further answers to the succeeding queries in connexion with this.

Page 28.

The General's assertion, that the power necessary to send a current when the earth completes one half of the circuit, must be twice as great as that used when a complete metallic circuit is formed by a return wire, is not only contradicted by Mr. Bain (see last line of page 93, *et seq.*), but is evidently in ignorance of the first rudiments of electrical science. The return wire being of very small diameter, *does* oppose some resistance to the fluid. The earth, however, opposes none at all, simply because of the large section of it which is opened to the fluid by the metallic plates, which are immersed, at each end of the wire. The current passing through the earth, may, therefore, be said to pass through a channel which is equal to a square foot or more.

Page 29.

The General sees no use in attaching a printing apparatus to an Electrical Telegraph. That it is, however, indispensably necessary to insure official responsibility, is shown in Mr. Finlaison's evidence, p. 111.

Page 30.

It does not distinctly appear in evidence, but it is, nevertheless, a fact, that Mr. Edward Cowper was sent down expressly to Edinburgh by the promoters of the Bill, in order to examine Mr. Bain's telegraph on the Edinburgh and Glasgow line, as also his electric clocks, and especially to see if Mr. Bain had used any of their patented apparatus (see top of p. 35). This explains his answer at the foot of p. 31:—"I visited it the next day when I went down, and I visited it as one of the public." But he candidly informed Mr. Bain, that he was sent on such an errand; adding, that he had previously told his employers that he would be no spy, but openly declare to Mr. Bain why he came. His silence as to any infringements of Mr. Bain on the patents of Cooke and Wheatstone is, therefore, very material. Still more so is his admission (p. 35), that Mr. Bain's mode of insulating the wire on the posts by asphalte, is entirely different from that of the other parties, and, in Mr. Bain's opinion, a superior method. There are two models referred to by Mr. Cowper in the 7th and 8th answers, at p. 30. One is a paper model, which he had made himself, in order to explain, at his own lecture, in March, 1844, Mr. Bain's

system of the I. and V. Telegraph. The other model referred to was Mr. Bain's own finished working model, then on the table of the Committee, which Mr. Cowper had also seen at Edinburgh on the railway. The two models are again contrasted in the last question of Mr. Webster, at p. 34.

Page 35 (*at the Top*).

Mr. Cowper is asked, "How many of Messrs. Cooke and Wheatstone's inventions has Mr. Bain used there?" (meaning between Edinburgh and Glasgow). He answers, "I have not gone into the patents for that purpose. I did not consider this to be a question of the value of the patents, and, *therefore, I merely went to a matter of fact.*" N.B. The matter of fact which he was probably sent to see was, not only whether Mr. Bain's telegraph was in operation with perfect efficiency, but also whether Mr. Bain had insulated his wires in the same way as his adversaries had patented. This last Mr. Cowper negatives distinctly in the next question but one, as is already referred to in the preceding note. He is then asked, "Has he (Mr. Bain) abandoned his own peculiar plan of asphalt and other matters in the telegraph from Edinburgh to Glasgow?"—Witness. "Do you mean in insulating the wire?" "Yes?"—Answer. "The wires are there carried on the tops of posts." "He does not use his asphalt?"—Answer. "No." At p. 95, Mr. Bain explains, that his principal reason for not using it in his own peculiar way on this railway—that is, in a bar of asphalt under ground—was, that the Directors would not permit the railway to be opened; and that the only other reason for not using it, applies to new railways, during the period in which the embankments might not have fully subsided; also, that it is a cheap mode of insulation. At p. 35, it appears from from Mr. Cowper, that he had, in fact, insulated his wires on the tops of the posts effectually with asphalt, as before stated.

Page 69.

The jumble alluded to by Mr. Cooper, at the foot of this page, is, indeed, a singular one. Dr. Watson, in 1748, discovered that a current of frictional electricity sent from the Leyden phial along a wire to some distance, returned, when the end of that wire was made to penetrate the earth, back to its source at the phial, all through the earth. Voltaic electricity was only discovered in 1800. But, in 1803, Aldini showed, by experiment, at Calais, that this last form of electricity, when sent from a battery of eighty cells (that is, when in a high state of intensity), would also return to its source through the earth or water. In 1838, Dr. Steinheil, of Munich, but with what power of intensity is unknown, applied this isolated fact, that the earth could complete the voltaic circuit, to the more economical working of electric telegraphs. On the 4th of June, 1842, Mr. Bain, perfectly ignorant of all the preceding discoveries, showed in Hyde Park the same property of the earth, *with a small battery sending very feeble currents*, and applied it to telegraphic purposes *for the first time in this country*, in his second patent just then specified, viz., on the 7th of June, 1842. Messrs. Cooke and Wheatstone repeated Mr. Bain's experiment with a battery, on or about the 5th of September, 1842, on Waterloo-bridge; and, on the 11th of that month, they took out their fifth patent, in which they also, in imitation of Mr. Bain, included the use of this property of the earth, as if it were a new discovery of their own. But on the 10th of October following, Mr. Bain made the further remarkable discovery, that *without any voltaic battery at all* the earth could be made to produce electric currents of considerable power, and of very valuable properties in other respects. This discovery he published, for the first time, in June, 1843, having included it in the specification of his third patent, lodged on the 27th of May preceding. As the new discovery was undeniable, his detractors most cunningly laboured to deprive him of the merit of it, by persuading General Pasley, when he, in February, 1844, was sent by the Admiralty to inspect Mr. Bain's telegraph, which was to print messages by the

currents *generated* from the earth *without any battery*, that this property of the earth to *produce* currents was one and the same with its other property of *conducting* currents when these are produced from the Leyden phial or from the voltaic apparatus. Being surprisingly ignorant of electric science, the General, as it appears, believed the story so plausibly told him, and on that authority affirmed that Mr. Bain had also, in this his last discovery, taken the merit of prior inventions. He now repeats, with singular confusion, the same jumble before the Committee, which Mr. Cooper, an old and experienced electrician, contradicts. The General had eagerly and voluntarily produced his official report (see p. 23), but was prevented by the Committee from giving it in as evidence, apparently from a disinclination to avail themselves of any documents from the Admiralty.

Page 103 (*at the Foot*).

In the preceding page, allusion is made to a statement in Mr. Hill's speech, that Cooke and Wheatstone had invented a portable telegraph, to be carried by a train, which, in case of accident, the guard could in any part of the line so apply to the wire as to make signals to the station, in advance or in the rear of the place where the accident might occur. This rested simply on the statement of counsel. They produced no model of such a machine, nor any witness to prove its utility or its practicability, or, in fact, that it ever had been tried. This defect one of the honourable members—not the counsel for the promoters—determined to supply by the cross-examination of Mr. Bain, so that he himself might be made, in this one respect at least, to confess his own inferiority to his opponents. At p. 102, he is asked, "Do you think that practicable?" He says, "I think it is. I consider that practicable, and, as far as I know, it belongs to these gentlemen." Q. "That would effectually prevent collisions?"—A. "It would help." Q. "And would help to save life and property?"—A. "Yes." The examination then suddenly diverges from the subject, and as suddenly returns to it, at the foot of p. 103. Then he is asked, "Can you by your system effectuate that in the event of any accident happening?"—A. "I give them entire credit for that." Q. "Your apparatus could not do that?"—A. "I have done nothing to effectuate it *as yet*." Here the subject of examination suddenly changes, to the grievous injury of Mr. Bain. Had it continued he would have stated, that a portable telegraph can only be worked by a portable battery; that in his opinion—and whether right or wrong, such is his opinion,—when an accident happens to a train, the confusion is always so great that the apparatus could not be got into working order in the same time as he by his system can now notify the disaster. A single signal from station No. 5 notifies to station No. 6, and to every other station, that the train A. has started. This train, if no accident had happened, would arrive at No. 6 by a given minute. No. 6 signals to No. 5, and every other station, that the train A. has *not* arrived at the time it ought to have; an engine from each station starts to see what is the matter, and in the meantime every other train is stopped. Now, each of the signals alluded to can be made in a second of time, and the delay is thus limited to the number of minutes elapsing between the time when the accident happens, and the time when the train ought to have arrived at No. 6. Mr. Bain thinks that this delay is less than that which would occur in getting ready the portable telegraph, and setting it to work. But, if the directors of railways should think otherwise, it is not for his interest to withhold a telegraph from every train. His own one of the I. and V., which was worked before the Committee, is portable enough; being only fifteen inches long, nine inches broad, and about six inches deep: a small battery, with a wire connecting the I. and V. telegraph with the main wire, numbering the posts or mile-stones along the line, would at once tell the stations in front and rear at which post or mile-stone the accident had happened. It requires little knowledge of law to say, that the *mere portability* of an instrument cannot be the subject of a patent. Mr. Bain is, surely, therefore at liberty to work

his own telegraph, whether it is fixed at any station, or fixed on a locomotive engine, so long as he carefully abstains from using the particular method patented by Messrs. Cooke and Wheatstone.

Page 113.

The shorthand-writer has omitted in this copy a part of the proceedings on the cross-examination of Mr. Finlaison. They were as follow:—

Mr. Hawes—The Committee do not see the propriety of entering into these domestic circumstances.

Mr. Hindmarsh—Sir, it is always allowed at *nisi prius* to show, but without imputing any want of veracity to Mr. Finlaison, that a witness may unconsciously have a bias on his mind from family connexions.

Mr. Hawes to the Witness—Mr. Finlaison, do you wish the questions and answers to be removed from the minutes?

Witness—Quite the contrary. I consider my connexion with Mr. Bain to be an honour to me.

Captain Gladstone—It is honourable to you both.

Chairman—No person who has heard the manner in which Mr. Bain gave his evidence before this Committee, can help feeling the highest respect for him.

[This hiatus must be apparent from the next question put by the Committee.]

THE END.

C. WHITING, BEAUFORT HOUSE, STRAND.

OF GALVANISM,

OR

VOLTAIC ELECTRICITY.

300. As to the nature of the cause of electrical phenomena, there is a great and mysterious uncertainty. By a majority of electricians, Dufay's suggestion of the existence of two fluids is sanctioned (E, 217, &c.*), while, by others, Franklin's idea of one fluid is preferred; yet philosophers of high pretensions question the existence of any imponderable matter. Whewell, of the University of Cambridge, in England, published an essay a few years since, of which it was the object to prove, that "all matter is heavy." Faraday, so highly distinguished by his Herculean researches, advanced the idea that electrical induction is the consequence of an action of contiguous ponderable particles; not an affection arising from their association with imponderable matter. In letters published in Silliman's Journal, I consider myself as having invalidated the positions thus taken by these eminent philosophers.

301. Nevertheless, I find it necessary to abandon the idea that there is any transfer of imponderable matter during electrical discharges. Latterly I have conjectured, that electrical phenomena are due to the opposite polarization of electric matter, which pervades all bodies and all space; so that the two electricities are the effects of the same matter in different states of polarization, and an electric current consists of a succession of polarizing impulses. To this subject I shall return when the facts on which this inference is founded shall be the subject of consideration.

302. Nevertheless, it seems universally to be deemed expedient to suppose, provisionally, the existence of fluid electric imponderable matter; and as the movements of one current are more easy to conceive of and describe,

* In referring to the numbers of paragraphs in the treatise on "Electricity Proper," I shall prefix the letter E: in referring to my Compendium, the letter C.

than those of two fluids, the language founded on the Franklinian theory is much used, even by those who assume the existence of two fluids.

303. Consistently with the hypothesis of Dufay (E, 217), there must, in every part of any active electric circuit, be two fluids flowing oppositely to each other. The quantity of either fluid must be increased as that of the other is diminished, so that there can neither be any diminution, nor any increase of the sum of the quantities of both fluids. Moreover, the current in an electric circuit can no more be directed from positive to negative, than from negative to positive. Nevertheless, the terms positive and negative, or minus and plus, are applied to the states of bodies; implying, of course, a deficiency in the one case, and a redundancy in the other. Moreover, arrows indicating the current to move from the positive to the negative pole are almost universally used.

304. I shall employ, on all occasions, a language corresponding with the theory of Franklin, wishing it to be understood, that when employing the words *electrical current*, as designating the phenomena of an active galvanic circuit, I do not mean to convey the idea that those words are sufficiently descriptive or accurate. The words electrical current should rather be understood to designate the unknown cause of certain effects, which are in some respects such as might result from a current of imponderable matter.

Of the Elementary Battery, or Simple Galvanic Pair, and its Circuit: more properly designated as a Galvanic Triad.

305. It is generally known that metals are liable to what is called corrosion, arising from a reciprocal action, or reaction, with certain gases or liquids; also, that some metals will react with liquids or gases, with which other metals will undergo no reaction.

306. It may be assumed as a general law, that when two metals are simultaneously exposed to a liquid, exercising with one of them a more energetic reaction than with the other, the phenomena will be such as to comport with the idea of an electrical current from the more susceptible metal, through the liquid, to the other metal; and

from this, through any competent conductor, back again to the first mentioned metal.* To this result a complete circuit is indispensable; and it is on the completion of the circuit that the phenomena take place which are assumed to demonstrate a current. It is on this account that when the tongue is situated between a plate of copper and a plate of zinc, no sensation is perceived until the projecting extremity of one, touches that of the other: but as soon as this contact is effected, a discharge takes place from the zinc to the copper (or silver) disc, which affects the taste somewhat like a feeble acid. Where the surfaces are large, the current may be indicated by the ignition of a wire made the medium of communication, or by the attraction and polarization of iron filings; but among the most competent means of detecting such currents, is the galvanometer or multiplier of Schweiger. In this a magnetic needle, situated within a coil of wire as represented in figure 1, by its deflection detects the existence of the most feeble galvanic current, which may be made to pass through the coil by means of a due communication with the ends, *a b*, of the wire.

Fig. 1.

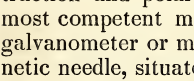
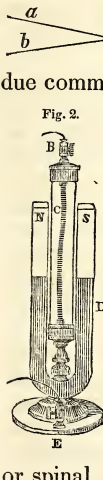


Fig. 2.



307. Hereafter the reaction of the galvano-electric current, so called, with the cause of magnetism, will be more fully brought into view, while at present it may be well to advert to another galvanoscope, which owes its existence to the same source. Fig. 2 represents this galvanoscope. When a small ribbon of gold leaf situated between the legs, N S, of the magnet, D, and parallel thereto, is made the medium of a minute galvanic discharge, the ribbon is swayed one way or the other, according to the direction of the current.

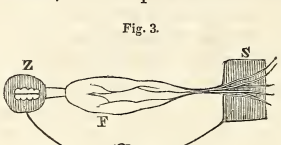
308. The tongue has been mentioned above as performing the office of a galvanoscope. Originally, the limb of a frog, with the lumbar or spinal nerves denuded, was employed by Galvani and his nephew, Aldini; and, recently, this organic instrument has been found by Matteucci, a distinguished modern in-

* I here state the opinion generally held, yet Sturgeon alleges, that in the case of iron and amalgamated zinc, although the former is much the most rapidly dissolved, it nevertheless acts as copper.

vestigator, to be competent to the detection of a current too feeble to affect a most delicate galvanometer, of a construction analogous to that above illustrated.

309. The following figure will give an idea of a frog prepared so as to answer as a galvanoscope. The denuded lumbar nerves, with a portion of the spine attached,

Fig. 3.



are represented at *z*, the feet at *s*. Now, if *z* be a plate of zinc, and *s* a plate of silver, copper, or platina, on making or breaking the circuit by the metallic arch, C, convulsions will be produced. When the interruptions and renewals of contact at one of the extremities of the arch are rapid, the agitation is incessant.

310. When the frog is used as a galvanoscope, the metallic plates should be perfectly homogeneous, so as of themselves to produce no discharge. In lieu of resting on metallic plates, the nerves and feet may each be enveloped in tin, or such lead foil as is used in tea chests.

311. Thus prepared, a dissected frog may be included in any circuit, in lieu of the galvanoscopes above described. Under those circumstances, the passage of the most minute galvano-electric current will be indicated by a corresponding tremulous motion in the organic instrument employed.

312. When a galvano-electric current is produced by two metallic plates, or any other competent masses, and an interposed exciting agent, they are usually called a galvanic *pair:* but as three elements are requisite to the characteristic effect, I prefer to call the apparatus which they form, a galvanic *triad* (306).

313. In the construction of galvanic triads, various forms may be given to the metals upon which the liquid is made to operate; and any two metals will be productive of analogous results, provided that one be more susceptible of erosion by the exciting liquid than the other.

Usually copper and zinc are employed, as combining in a preëminent degree, efficiency with cheapness. Yet silver would be preferable to copper, gold to silver, and platinum probably to gold.

314. It follows, that whatever may be demonstrated with respect to copper and zinc, will apply, more or less, in the case of other metals. Hence C and Z, the initials of copper and zinc, may be considered severally as representing two metals, one of greater, the other of inferior susceptibility of erosion. The electric relation of these metals may be changed by varying the exciting liquid. Thus, for instance, in a galvanic arrangement, in which copper and zinc should be subjected to ammonia, which acts upon copper more than upon zinc, the latter metal would, in a simple galvanic circuit, give electricity to the former. It appears, also, that in lieu of two metals and one liquid, we may employ two liquids with one metal; or one metal with one liquid may be employed, provided the surfaces be in a different state as to roughness, since a more powerful reaction takes place with the rougher surface.

315. The energy of the current varies also with the greater or less disposition of the negative, or less oxidizable metal, to become tarnished by oxidation, or depositions from the liquid, and of being partially dissolved and precipitated on the other metal. These evils are so great in the case of zinc and copper, as to cause a battery constructed of them, without any remedial contrivance, to lose almost all its efficiency, before the zinc is exhausted. The zinc becomes so completely coated by a mixture* of its suboxide with metallic copper, that due access of the acid is prevented.

316. As either silver, gold, or platinum, differ from zinc more than copper does, as to liability to erosion, were it not for their superior costliness they would be preferable to this last mentioned metal. Platinum is preëminently preferable, being less susceptible of change than gold. A minute quantity of this metal, precipitated on the surface of silver or copper, has been found to make these metals

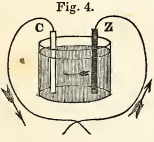
* This mixture, after being softened by soaking in water, and then scraped off, I found, in one instance, to grow hot spontaneously. Probably this arose from a galvano-chemical reaction between the moisture and the copper and zinc particles, during which these were acquiring an additional quantity of oxygen.

more efficacious in a galvanic triad, by diminishing the injurious tendency to coherence, between them and hydrogen. Recently it has been found, that either plumbago, coke, or the indurated carbon sublimed in vessels for evolving gas from bituminous coal, may be substituted for the copper in a triad.

317. From the phenomena of electrical fishes, and those observed by Matteucci in the muscles of frogs, fishes, and warm blooded animals, it is evident that the law, which has been assumed to be in operation in the case of metals, must prevail no less where organic substances are solely concerned (306).

318. Although at this stage of our illustration, any attempt to explain the theory or construction of the multiplier, or galvanometer, would be premature, it will be highly advantageous to employ it as the best means of detecting the direction and force of a galvanic current. At present, it will be sufficient to state, that when a galvanic discharge takes place through a wire, as from the copper plate C, to the zinc plate Z, both subjected to diluted acid, as in fig. 4, the magnetic needle has a tendency to arrange itself, at right angles to the path of the current,* and that consequently, if the current be made to pass parallel to the needle, a deflection in proportion to the quantity of fluid which passes, will ensue. The interposition of the coil of the galvanometer, merely reiterates the influence of the current, by causing it to circulate many times about the needle. See Electro-magnetism, for various engravings and descriptions of this instrument.

Fig. 4.



319. The direction of the galvanic current is known, from the manner in which the needle is deflected; since when the current is above, and flows in a direction parallel to the meridian, from south to north, the north pole is deflected so as to point westward, and of course the south pole, oppositely deflected, points eastward. When a similar current is flowing in the same direction below the needle, the deflection is the reverse of that just described;

* More accurately, it may be said to take the attitude of a tangent to the circumference of a cylinder, in the axis of which the current flows.

but in any case, reversing the direction of the current, reverses the deflection.

320. In an elementary battery, or triad, consisting of copper, zinc and water, or any aqueous solution, the oxidation of the zinc is, as already suggested, indispensable to the production of the phenomena, which are conventionally attributed to an electrical current circulating from the zinc, through the liquid to the copper, and back again to the zinc. Under these circumstances, as the oxygen of the water combines with the zinc, it might be expected, that hydrogen, the other elementary ingredient of the liquid, would be liberated at the surface of the metal, as is known to be the fact, when zinc in an impure state, as found in commerce, is subjected to diluted sulphuric acid. But, in fact, so long as there is a metallic communication between the plates, the hydrogen will be liberated only at the surface of the copper. According to Faraday, there is no reaction and consequent evolution of hydrogen, when zinc, purified by distillation, is subjected, per se, to diluted sulphuric acid; nor from commercial zinc, if the surface be amalgamated, or in other words, coated by a film of mercury. The effect of this coating is to prevent the formation of local circuits, between the zinc and certain metallic impurities which it contains. A homogeneous substance is produced, which, per se, is scarcely susceptible of reaction with diluted sulphuric acid.

321. But although neither *pure* zinc, nor *impure* zinc when *amalgamated*, has, per se, any reaction with the water of diluted sulphuric acid, yet if touched by a piece of copper previously immersed in the solution, the oxygen of the water combines more or less with the zinc, while the hydrogen is copiously evolved from the cupreous surface.

322. This may be considered as another of the characteristic features of a galvanic circuit, though it cannot be so conveniently nor satisfactorily made manifest as the indications above cited (306, 307, 309).

323. The characteristic phenomena which have been described as resulting from a galvanic triad, are not inseparately associated with any particular forms of the generating surfaces, or arrangement of them. The same extent of superficies may be more efficacious when arranged in one way than in another, or may vary in its efficacy

with the energy of the exciting liquid; but whether either or both of the metals be used in one plate, or in several, does not alter the characteristic features of the circuit as they have been described.

Of the Calorimotor.

324. In 1818 I contrived a modification of the galvanic triad or elementary battery, which I designated as a calorimotor or heat mover, under the idea that a current of heat no less than one of electricity, is an effect of the galvano motive power.*

325. The calorimotor consisted of twenty-one plates of copper communicating by a metallic strap, and twenty plates of zinc similarly associated, the plates of the one set being alternated between those of the other. In an apparatus thus constructed, the zinc is every where opposed by copper, so that both of its surfaces become equally efficacious. Still this apparatus, although consisting of forty-one metallic sheets, and twenty interstices replete with the exciting liquid, comprises only the three elements of a gal-

* The ignition and deflagration of wires by the galvanic current has, by philosophers generally, been ascribed solely to electricity; the heat and light evolved having been treated as secondary effects. But as, agreeably to the observation of Davy, sanctioned by general experience, a finite portion of wire, exposed in the voltaic circuit, may be kept ignited for an unlimited time, it follows, that if heat be material, it cannot be supplied by the wire, and must be supposed to flow from the same source as the accompanying electricity. Considering the imponderable fluid put into circulation by galvanic reaction, as consisting of caloric as well as electricity, I inferred that the proportion of the caloric increased with the size of the pairs, that of the electricity with the number; and that in a large apparatus of one pair, the latter fluid was in a minimum proportion, so that it was mainly caloric, which was made to circulate by a large galvanic pair which I had constructed.

It is demonstrated by the phenomena of *thermo-electricity*, of which an account will be given in due course, that a current of heat may be the primary cause of a galvanic current, in thermo-electric apparatus, just as much as a current of electricity is the cause of an evolution of heat from an apparatus, such as above described, called hydro-electric, because a liquid is requisite to the result. It seems, therefore, reasonable to consider, that both caloric and electricity may be products either of *galvano* or *thermo*-electric reaction; and that if heat be a secondary product in one case, electricity is no less so in the other. There is the most ample proof that the cause of the one, as well as of the other, exists in metals to an enormous degree. The arguments against the idea that a fluid is the cause of electricity, are, it seems to me, more difficult to answer than any that can be adduced against the existence of a material cause of calorific repulsion.

Contemplating a galvanic pair as simply a mover of the electric fluid, Volta had called such pairs, as existing in his series, electromotors. By analogy, I applied the term calorimotor to signify the large pair or heat mover above mentioned.

The opinion above alluded to, that the heat of an active galvanic circuit is not an *electrical effect*, as generally supposed, but that, on the contrary, caloric and electricity are connate and collateral products of galvanic reaction, was entertained when the causes, both of the calorific and electrical phenomena, were generally considered as material fluids, the electro-magnetic powers of the circuit in question being unknown. It will, in due course, be explained, that I am now disposed to consider the powers of the active circuit as the consequence of waves of polarization, and probably of concomitant vibrations or movements, in one or more imponderable principles, which, pervading all space, are combined more or less in a condensed state with ponderable atoms, and enter enormously into the constitution of perfect conductors, in other words, metals.

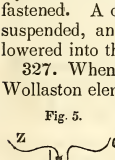
But this view of the subject is entirely consistent with the inference, that heat and electricity are connate and collateral products of galvanic reaction, and that heat is no more an effect of electricity, than electricity is an effect of heat.

vanic triad, one associated zinc surface, one associated copper surface, and the liquid interposed every where between them.

326. I ought to mention, that by means of a silver thimble, within which a minute piece of zinc was supported and insulated, Wollaston made an elementary battery capable of igniting a minute platina wire. In enlarging the size of the galvanic triad, as above stated, my course was diametrically opposite. Several methods of accomplishing this design occurred; among others, I contemplated concentric coils of copper and zinc, the former being so wound as to surround the zinc completely. Also, to unite several sheets of copper to one bar of metal, and several zinc sheets to another bar, the zinc and copper alternating. To the latter plan I gave the preference. Twenty sheets of copper, and a like number of zinc sheets, associated as above described, were secured in a wooden frame, so as to leave about a quarter of an inch between them. One end of a rope, passing over a pulley, was attached to the frame, while to the other end a counter weight was fastened. A cubical box of suitable size being placed under the frame thus suspended, and supplied with diluted sulphuric acid, the frame could be lowered into the acid liquid, or lifted out in an instant.

327. When one plate of zinc is placed between two of copper, as in the Wollaston elementary battery, represented by the adjoining cut, out of four copper surfaces two are useless; but in a calorimotor where the same quantity of zinc is used so as to form several plates, say four, for instance, five copper plates of the same size, will be sufficient to constitute a calorimotor in which each zinc plate will be opposed by a cupreous surface, and only the outermost surfaces, the two external copper plates, will be useless. Hence, of the ten surfaces in the five copper plates, all but two are brought into action.

Fig. 5.



328. A battery, resembling the calorimotor in the alternation of surfaces, has lately been constructed, in which iron plates are made to perform the office of those of copper: much merit is attached to the construction, no reference being made to its previous employment by me.

329. While I was engaged in these experiments, Mr. Lukens, to whom I had mentioned the various plans which I had projected, of calorimotors, put into operation, with the aid of Dr. Patterson, the plan of concentric coils. Although this apparatus had less surface than that which I had constructed, and would not heat as large a wire as the latter, yet it communicated a much higher ignition to a small wire than mine was capable of producing.

330. Soon after this experiment of Patterson and Lukens, J. P. Wetherill, Esq., had a pair made in the form of concentric coils, of one hundred square feet of surface. From this great results were expected, and a large assemblage, of those interested in such experiments, attended to see the mammoth pair tried. But to the surprise of all present, it did not induce even a red heat in connecting wires, such as had been vividly ignited by my apparatus, or that of Patterson and Lukens.*

* Some time after these large pairs were constructed, similar apparatus was made by Mr. Pepys, of London, and likewise by Col. Offerhaus, on the continent; and although a memoir, in which I gave an account of these experiments, was published in Silliman's Journal, and in the Annals of Philosophy, Pepys' apparatus of concentric coils has been treated of as an original contrivance in Turner's Chemistry, and elsewhere. The apparatus of Offerhaus, though made long after those constructed

331. It struck me afterwards, that in a very large pair, the intensity does not increase with the quantity of the fluid generated, since the imponderable matter, or the waves of polarization, cannot be concentrated upon a given small point of afflux, as soon from a large surface, as from a small one.

332. It is analogous to the case of a small and a large stratum of water,

by Patterson and Lukens, and by Wetherill, was described as if it had been a novel form of apparatus.

Finding that in consequence of the low intensity of the current from my calorimotor, consisting of one pair formed of two surfaces of fifty square feet, it did not produce a heat sufficient for the active deflagration of wires, I subsequently converted it into an apparatus of two pairs, the copper sheets of one alternating with the zinc sheets of the other.

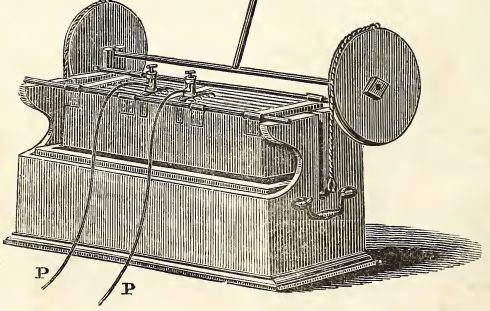
Two of the surfaces were united by a mass of solder. To the others forceps were soldered, into which the ends of the wire were fastened, which was to be made the medium of discharge. This form of the calorimotor I have found of great use, as the means of igniting gaseous mixtures in eudiometrical experiments, and other processes requiring ignition in close vessels.

Figure 5 represents a calorimotor of four pairs, so constructed that the diluted acid contained in a vessel of suitable form and size is brought into contact with the metallic surfaces, by applying the hand duly to the end of a lever associated with two pulleys and two cords, attached severally to the ends of the vessel. The cords, by being wound up on the pulleys, raise the copper vessel so as to cause the plates to be immersed in the diluted acid.

The two forms of the calorimotor represented by fig. 6 and 7, have been much used by me for what is described in my Compendium as "*galvano ignition.*" (C, 335.) Within any cavity, ignition of any intensity short of fusing platina may be produced, by making a platina wire the subject of a galvanic discharge from an instrument of this kind. I first resorted to this process in the year 1820, for the purpose of igniting gaseous mixtures in eudiometers of various forms. In June, 1831, I applied it to ignite gunpowder in rock blasting; and to this object it was subsequently applied, agreeably to my recommendation, by Colonel Pasley, Professor O'Shocnessy, and others.

Engraving and Description of a Calorimotor of Four Pairs, or Triads.

Fig. 6.



both of one depth. It is well known that the surface in both, being sustained at the same height above the points of efflux, a jet from the former stratum will go as far as one of the same diameter, emitted by the latter.

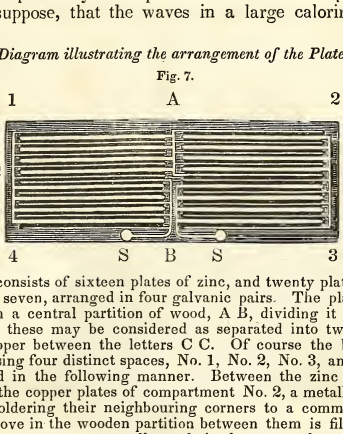
333. There was, however, one characteristic noticed by me, in which this analogy does not hold; I allude to the fact, that fine wire will not fuse when made the medium of discharge from a very large pair, although the same wire may be fused by a small one.

334. The capillary wire ignited by the thimble battery of Wollaston, could not be similarly ignited by a calorimotor of fifty square feet. I have mentioned that the coil of Patterson and Lukens ignited an iron wire about No. 24, more intensely than my larger apparatus of one pair, consisting of alternate plates.

335. Adopting the idea, that a current of electricity consists of waves of polarization, the mystery may be thus explained. The application of a wire to the electrodes, disproportionate in sectional area to the triad, the circuit of which it is employed to close, impedes the polarization of the greater part of the masses which enter into the construction of the triad. Hence the polarizable matter within those masses is prevented from attaining even that low degree of tension, of which one triad is susceptible when its circuit is completed by a competent conductor. It appears, therefore, reasonable to suppose, that the waves in a large calorimotor move less

Diagram illustrating the arrangement of the Plates.

Fig. 7.



This machine consists of sixteen plates of zinc, and twenty plates of copper, each twelve inches by seven, arranged in four galvanic pairs. The plates are supported within a box with a central partition of wood, A B, dividing it into two compartments. Each of these may be considered as separated into two subdivisions, by four plates of copper between the letters C C. Of course the box may be considered as comprising four distinct spaces, No. 1, No. 2, No. 3, and No. 4. The circuit is established in the following manner. Between the zinc plates of compartment No. 1, and the copper plates of compartment No. 2, a metallic communication is produced, by soldering their neighbouring corners to a common mass of solder, with which a groove in the wooden partition between them is filled. With similar masses of solder, two grooves severally made in the upper edges of each end of the box are supplied. To one of them, the corners of all the copper plates of space No. 1, and the zinc of space No. 4, are soldered. To the other, the zinc plates of space No. 2, and the copper plates of space No. 3, are soldered in like manner. Lastly, the zinc plates of No. 3 are connected by solder in a groove, and the copper plates of No. 4 are in like manner connected by solder in another groove. Upon the ends, S S, of the solder just mentioned, the gallows screws are severally soldered, and to these the rods, P P, called poles, are fastened. The means by which the acid is made to act upon the plates, must be sufficiently evident from inspection. Depressing the handle causes the wheels to revolve, and thus, by means of the cord which works in their grooved circumferences, to lift the receptacle which holds the acid, until this occupies the interstices between the plates.

The rationale of the increase of intensity resulting from the above described construction, will be given under the head of *compound circuits.*

speedily, while they have, on the average, much further to go than those created in comparatively minute apparatus, essentially of the same construction.

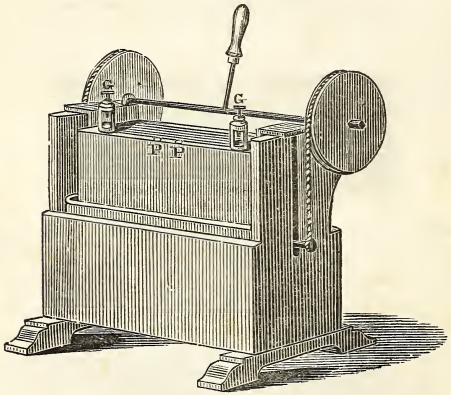
336. There seems to be an analogy between the part performed by a conductor in completing a galvanic circuit, and that of a keeper in completing the circuit of a magnet so far as this; that in either case, the body by which the completion is accomplished, is the cause as well as the subject of the resulting power.

Of the Galvanoscopic Frog.

337. It must follow, from the facts already alluded to, that the limb of a frog must combine all that is essential to a galvanic triad; and, agreeably to the observations of Matteucci,* sections of the muscles either of warm or cold-blooded animals are competent to give discharges analogous to those of a very feeble galvanic triad. The

Calorimotor of Two Pairs, or Triads.

Fig. 8.



The apparatus represented by the preceding figure is a calorimotor quite analogous in construction to that above described, but which differs from it in being of only one-fourth of the size, and in consisting of two pairs instead of four. The plates are nine inches by seven. There are four of zinc, and six of copper.

In the form of sheets arranged as two pairs alternating, Faraday, in some of his researches, employed a calorimotor.

Of course, when consisting of more than one triad, the calorimotor ceases to come under the head of simple circuits. It operates, when constituted of more than one triad, upon the principle of a compound circuit, which will be explained in the next chapter.

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* Annales de Chymie et de Physique, Troisieme Serie, Tom. 7, page 425.

organs by which electrical fishes are enabled to give shocks to produce ignition, or deviations of the galvanometrical needle, are, no doubt, a series of galvanic triads, in which organic masses, associated in a series voltaically, perform the office of the plates in galvanic triads, forming a compound circuit, of which the description and explanation is the subject of the next chapter.

Experimental Illustration.

338. The electrical excitement arising from the contact of copper and zinc, shown by means of the single leaf electrometer.

339. Effect of the active circuit upon Schweiger's galvanometer and the gold leaf galvanoscope. Also, upon a leech or prepared frog.

340. Disks of zinc, provided for the purpose of producing a galvanic discharge through the tongue, when severally placed over and under it; the projecting limb of each disk being brought into contact.

341. A plate of copper and a plate of zinc, connected by a small wire, being plunged into a vessel containing a dilute acid, the ignition of the wire is produced. The same result obtained, by concentric coils of sheet copper and sheet zinc: also by several plates of copper and zinc, alternated with each other; all the copper plates being associated by one metallic bar, and all the zinc plates by another. These heterogeneous surfaces have, every where, interstices between them, and are connected only by a small wire, which is deflagrated as soon as they are immersed in an acid.

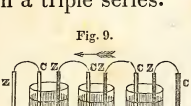
CHAPTER II.

OF COMPOUND CIRCUITS, OR VOLTAIC SERIES.

342. Having briefly described the construction and the process of a single galvanic triad, or elementary battery as it is usually called, I will, in the next place, direct at-

tention to the compound or complex circuits, consisting of two or more triads. For the illustration of this more complicated form of the galvanic battery, a series of three triads will answer every purpose, since, were any number, however great, interposed between the terminating triads, each would be in a situation, theoretically and practically, perfectly analogous to the triad occupying the mean space in a triple series.

Fig. 9.



343. Let us suppose three galvanic triads like that represented by Fig. 9, to be situated side by side, no metallic communication existing between the plates of any one triad, while each plate in each communicates, by a metallic conductor, with one of a different metal in one of the triads on either side; also, let the extreme plates communicate by wires, meeting as represented.

344. The plates of neither triad communicating *directly*, neither can form an *independent* circuit, but still any of them may make a discharge through the complex conductor, formed by the uniting wires, and the intervening portions of the exciting liquid. It follows, that if the two plates in the exterior receptacles were both of one metal, so as to be incapable of producing a galvanic current, the middle triad would act as a simple elementary battery, performing its circuit through a complicated conductor. But as in the actual construction, the plates of each triad are similarly excited, the disposition to discharge electricity exists in each. In other words, each copper plate becomes surcharged, each zinc plate deficient, to a commensurate extent.* Hence, the redundancy engendered in the copper plates, is neutralized by the deficiency engendered in the zinc plates; and no more of the fluid can pass at any point which may be selected, than that which is generated by the two plates, between which the selected point exists. Intensity is all that is gained in the complex circuit. As all the pairs have to use one complicated circuit, they all coöperate to effect a current in that circuit.

* It should be recollected that the zinc, discharging through the liquid to the copper, renders this metal proportionably redundant, and becomes proportionably deficient.

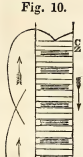
345. During the operation of a single circuit, the discharge from the zinc to the copper, through the liquid, is compensated by that of the copper to the zinc, through the wire, excepting so far as the current is retarded by the obstruction created by the nature or dimensions of the conductor interposed.

346. In the compound circuit, the discharge from the zinc to the copper of each triad, through the liquid, is compensated by the discharge from the copper of one pair to the zinc of the other, and as the deficiency in each zinc plate is exactly equivalent to the surcharge produced in each copper plate, it is evident that the equilibrium must be restored almost as soon as destroyed, where the conducting communication between each pair and that between the extremities is very ample. But after making the communications ample every where else, if there be a deficiency arising either from the size, or the nature of the interposed body, between any two of the triads, the whole of the series will coöperate to effect a discharge through it. So long as this cannot be accomplished, the copper and zinc plate of every triad is brought into an opposite state of polarity, producing a tension, or in other words, an effort to effect a discharge. Hence, the intensity of the effort to overcome the obstruction, is as the number of triads, excepting the loss by retroconduction. This loss necessarily augments in an increasing ratio, so that there is probably a point, at which any numeric extension would injure by promoting retroconduction, more than it would contribute to the intensity.

347. Usually, a galvanic series is considered as composed merely of *pairs*, each consisting of an electro-negative and an electro-positive metal, copper and zinc, for instance. This was the idea of the inventor, who erroneously ascribed the energy of his apparatus to an electromotive power in the metals, treating the liquid interposed as performing only the humble office of transmitting the electricity from one of the electro-motive surfaces to the other.

348. The first construction of the Voltaic series was that of a pile of such pairs, separated from each other by moistened cloth or pasteboard. Hence, the appellation *Voltaic pile* is often used to signify a series of galvanic triads in any form. Fig. 10 may give an idea of the cele-

Fig. 10.



brated pile of Volta, which has immortalized the name of the inventor, and given rise to results unsurpassed in importance by those of any other invention. The first four, and the last two zinc and copper plates, are distinguished by the letters, C Z. By these means the relative position of all the plates may be understood, as well as those of the disks of cloth represented by intervening dark lines.

349. The following is the account given of his invention by Volta, in a letter to the president of the Royal Philosophical Society of Great Britain:

350. "The principal result is the construction of an apparatus which, as respects the shocks it is capable of giving to the arm, resembles that of a Leyden jar, or of an electrical battery feebly charged, but which shall act incessantly, being self charged after each explosion; which is, in fact, endowed with an inexhaustible charge, or perpetual action or impulsion, upon the electric fluid, but which is peculiar in this power of continuous action; and, moreover, is peculiar in not consisting, like the ordinary batteries, of one or more jars coated by conductors. The apparatus of which I write, is an assemblage of good conductors of different kinds, arranged in a certain manner. Twenty, forty, or sixty, pieces of copper (or better of silver), each applied to a piece of tin (or much better of zinc), and an equal number of strata of water, brine, ley (or other solution which conducts better than water alone), or pieces of card, skin, &c., soaked with any of these liquids; these being interposed between each couple of the different metals, alternately, so as to have the three kinds of conductors arranged in the same order throughout. Such is the constitution of the new instrument. This instrument imitates, as I have alleged, the effect of Leyden jars, or batteries, in giving similar shocks, which are, nevertheless, as evinced either by the noise or force of the explosion, the length of the spark, &c., very inferior in intensity to those given by batteries of coated glass, when highly charged. Although equivalent only to a battery of immense surface, very feebly excited, the pile has the preëminent virtue of not requiring to be charged in advance, by an electrical machine, in order to give shocks as often as it may be properly touched.

351. "I propose to call this instrument the artificial electrical organ, as having both in principle and form, as I have constructed it, much greater resemblance to the electrical organ of the torpedo, than any other known electrical apparatus. In truth, it is no less than the latter, composed entirely of conductors."

352. After giving minute instructions for the construction of his pile, the author states, "should it comprise twenty of the metallic pairs, it will not only be competent to cause the leaves of a condensing electrometer to diverge, but will give a charge adequate to a spark, and to create a sensation in the fingers, as often as they may be brought into contact with the extremities simultaneously, resembling that of a torpedo, which has been extremely enfeebled."

353. It is remarkable, that Volta in this communication took not the smallest notice of the rapid decline of power, which ensues in his apparatus, and the fact that it soon becomes comparatively effete. The only recog-

nition which he makes of this decline is accompanied by the suggestion, that being caused by the evaporation of the moisture, it might be prevented by a resinous covering. But the inadequacy of the escape of moisture to explain the diminution of power, ought to have been sufficiently evident from the striking fact, that this diminution ensues in the couronne des tasses. In this apparatus, as well as in the pile, the acid becomes saturated, and the plates coated with reduced copper and suboxide of zinc, although, from the ample supply of water, there can be no injurious desiccation.

Of the True Members of a Voltaic Series.

354. I have endeavoured to make it evident, that the apparatus, which has been called an elementary battery, or galvanic pair, is more properly considered and designated as a galvanic triad; since to form it requires, at least, three agents. Consistently, the metallic pair, belonging to each triad, comprised in a voltaic series, does not consist of the plates which touch each other, but of those which are separated by the exciting liquid, whether held in cells or interposed cloth. Erroneously ascribing the power of his series to an electromotive power, and conceiving the agent intervening between the metallic couple as acting merely as a conductor, Volta constructed his pile, as represented by fig. 10, in which there are two useless plates, one of each metal, at the extremities. The series really commences with the lowermost zinc plate, and ends with the uppermost copper plate, and as the current is from zinc to copper within, and from copper to zinc without, as represented by the arrows, fig. 10, it follows, that when rightly constructed, the copper end is positive, the zinc end negative. The addition, by Volta and his imitators, of two useless plates, as above stated, has led to a general impression, that the true zinc end of a series is positive, and the true copper end, of course, negative, contrary to the real state of the case.

355. I consider the original pile of Volta, and every other modification of the voltaic battery, as consisting of a series of elementary batteries, each alone competent to supply a galvanic current, and to the accumulated powers of which the energy of the whole is due. But such batteries do not severally consist of the two plates of metal which are in contact, or united by a wire or strap, but of two plates, forming a triad with the interposed exciting liquid. But if such a pile consists of such triads, making the base negative, we must begin the pile with zinc, and of course terminate it with copper.

356. Since, when a wire or strap is made to proceed into a liquid, from the copper plate really forming the positive or delivering end of the series, it occupies the place which a zinc plate would occupy in the next additional cell in the couronne des tasses, or Babbington's apparatus, were the series extended, Daniell designates the surface of such a wire or strap, as the "zincode." This appears to me objectionable, since it tends to produce a narrow association of a general property with a particular metal. Though it may be truly alleged, that the zincode occupies the place which the generating metal zinc, would occupy; yet, nevertheless, it does not act as a generating metal. It does not, like the preceding zinc plate, contribute to the current.

357. Faraday has proposed to call the poles of the voltaic series, electrodes, from ὁδός, a way, and electron; the sectional polar areas thus designated, being the passages through which the electricity is assumed to flow into or out of the series when the circuit is in operation. Supposing the wires of the series, those of fig 9, for instance, to be introduced into water,

so as to take a portion of this liquid into the circuit, that end of the row of atoms of water which touches the wire proceeding from the copper plate in the liquid, is called by the same author the *anode*, while the other end of the row in contact with the wire, proceeding from the first zinc plate in the series, is called the *cathode*.

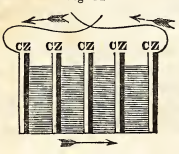
358. In order to understand the etymology of these words, it may be expedient to refer to the fact already mentioned, that the magnetic needle tends always to take a position at right angles to an electrical current, to the influence of which it is sufficiently exposed. The direction of the compass needle is ascribed to such a current, caused by the progression of the solar heat from east to west, consequent to the diurnal rotation of the earth. In the case of any portion of the crust of the earth subjected to the thermo-electric currents, originating as suggested, the fluid will enter from the east, or where the sun rises, hence anode, from ανω, upwards, and οδος, a way. Again, the fluid passing out westward, we have cathode, from κατα, downwards, and οδος. It follows, that any mass of liquid or other body made to complete the circuit, by having each of its extremities in contact with the ends of the wires forming the electrodes of a galvanic battery, the part in contact with the positive pole will be the anode, while the part in contact with the negative pole will be the cathode.

359. I shall, however, continue to designate the poles as they have been heretofore named, using also Faraday's new appellation (electrode) for either. Noad has judiciously, as I think, proposed that the positive pole be designated as the anelectrode, the negative pole as the cathelectrode.

360. The process of decomposition, as effected by the voltaic current, is, by Faraday, designated electrolysis, from *electron*, and *luo*, to unbind or free from bondage. A substance, susceptible of this process, is designated as an electrolyte, and is said, when subjected to it, to be electrolysed. Its elementary constituents are called *ions*, from *io*, to go. That which is evolved at the anode, anelectrode or positive pole, is called an anion, while the other, which is evolved from the cathode, cathelectrode or negative pole, is called a cation or cathion.

361. In stating the dimensions of a pile, it is most convenient to mention the size of the pairs, and the whole number associated in the series. As there must be two plates for every triad, this mode of estimation causes no error in fact, however it may tend, when unnoticed, to be productive of an hypothetical misconception. In the voltaic pile, fig. 10, the electro-negative and electro-positive metals, copper and zinc for instance, are in contact. Hence, there is no necessity for a conjunctive wire or strap to enable the copper of one triad to discharge to the zinc of the other, as in figures 4 and 9. I hold this language, under the impression that the elementary batteries, or triads, forming the series, consist each *of a copper and zinc plate which do not touch or communicate otherwise than through the liquid*, not of those which are in *contact* as in the pile, or connected by a wire as in the couronne des tasses, figure 9.

Fig. 11.



362. Soon after the pile and the couronne des tasses were invented by Volta, another form of the voltaic series was contrived by Cruikshank, one of the most distinguished chemists of his time. Of this, figure 11 is a representation; usually it is designated as the Cruikshank trough. The pairs in this apparatus consist of a zinc and copper plate of similar dimensions, united so as to bring their corresponding surfaces in contact throughout. Each

pair forms one partition, consisting, on one side, of copper, on the other, of zinc. The partitions thus formed being inserted in an horizontal trough, have between them interstitial cavities for holding the acids, and which consequently perform the office of the cloth in the voltaic pile. Of course, the metals must be in the same alternate order as in the pile. The right side of the partitions being all of one kind of metal, those on the left must all be of the other: so that looking down at the trough obliquely from one end, we see none but copper surfaces; when looking from the other end, we see none but zinc. It is better, however, to have an extra copper plate at each end, to which to solder the rods or wires employed to communicate the galvanic current, or to act as the electrodes. These plates should be attached severally to the pieces of board forming the ends of the trough. This successive alternation of copper and zinc, or any other masses having a similar efficacy, whether organic or inorganic, I shall designate as *voltaic order*, being that which is essential to any modification of what we call the voltaic series, whether natural or artificial.

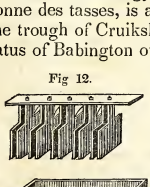
363. The analogy between the Cruikshank trough and the pile must be evident, since, if we place the trough upright, and after filling the cells between the pairs with moistened cloth, remove the wood, we shall have the voltaic pile in the form of a rectangular prism.

364. The trough of Cruikshank has great advantages over the pile, or the couronne des tasses. As the energy of the current diminishes with the activity of the acid, and this is lessened in abundance and strength by reaction with the zinc, the quantity which can be held by the cloth is soon exhausted; and although, in the couronne des tasses, the supply of acid was as much too great, as in the pile it was too small, the plates could not be kept parallel, nor sufficiently near without liability to touch each other. In the trough there was an abundance of acid, and the plates, however approximated, were secure from contact: moreover, the Cruikshank trough, as since modified by me, in order to comprise an equivalent degree of efficacy, need not occupy a tenth part of the space required by the couronne des tasses. Again, the contact is immediate and more effectual between the zinc of one pair, and the copper of another.

365. The direction of the current in the trough is indicated by the arrows in the figure. It will be observed, to obey the general law of the circulation, as already mentioned, it proceeds from zinc to copper within the liquid, and from copper to zinc through the wire.

366. The analogy between Babington's apparatus, fig. 12, and the couronne des tasses, is as great as that which has been shown to exist between the trough of Cruikshank and the pile of Volta; the superiority of the apparatus of Babington over the couronne des tasses, being equally striking.

Fig 12.



367. In Babington's apparatus, a trough of porcelain is so constructed, as to have in it partitions of the same material, dividing the interior into ten or more cells of a rectangular shape. With a view to economy both of the sheet metal employed and space, the plates are made also of a corresponding rectangular shape. We have seen that in the pile, and in the Cruikshank trough, the triads communicate by direct contact. In the apparatus of Babington, a communication between them is established by straps of copper, which serve also to attach severally to one beam each couple appertaining to one trough, so that they may be simultaneously introduced into or

removed from the cells. By these means, the operator was enabled to cause the reaction between the plates and exciting liquid to begin or to terminate with greater conveniency. It must be evident, that in the series under consideration formed with porcelain troughs, cells are substituted for the tumblers of the couronne des tasses, while straps are substituted for the wires, and square plates for disks. The apparatus in question is, therefore, virtually a couronne des tasses, very much improved as to compactness, convenience, and efficacy.

368. The great apparatus of Davy consisted of two hundred porcelain troughs of ten pairs each, upon Babington's plan, and comprised, of course, two thousand triads.

369. Subsequently, agreeably to the suggestion of Wollaston, in an apparatus, otherwise constructed like that last described, the zinc was surrounded by copper, contact being prevented. By these means, the efficacy of the zinc was conceived to be increased by one-half.

370. The celebrated apparatus of Children was made agreeably to Wollaston's plan; it consisted of twenty pairs, each comprising two sheets of copper coupled by a metallic strap, and one of zinc. The zinc sheet in each pair was situated between the two sheets of copper. Each sheet measured six feet by two feet eight inches.

371. Subsequently, adopting the same plan as in Wollaston's battery, as respects surrounding the zinc by copper, I made an apparatus of three hundred pairs, in which the vertical edges of the zinc were protected by the copper, instead of the upper and lower edges. This difference I found of importance in diminishing the necessity of insulation. The copper cases thus constructed were separated by veneers of mahogany; yet they were not insulated any further than as copper serves to insulate the peculiar polarity on which voltaic action depends. But the most important change in the arrangement of my apparatus, was that by which it was permitted to throw the whole of the acid on or off of a series at once.*

* The opinions of Faraday respecting the superior efficacy of the deflagrator, will be found in the following abstract republished in Silliman's American Journal of Sciences. They are preceded by the following introductory remarks by the distinguished editor of that Journal. See Vol. XXXII. page 170, for 1833.

"An account was given in this Journal (American Journal of Science, 1821, Volume 3) by Dr. Hare, of his galvanic deflagrators, and of their great power in proportion to their size in producing intense ignition. Not long after, the experiments of Dr. Hare were, with some additions, repeated by us, and the results fully confirming the allegations of the inventor were also published in this work. Although Dr. Hare's memoirs and ours, with engravings, were published in the Annals of Philosophy and Philosophical Magazine, London, yet it does not appear that his deflagrators were imitated in Europe, the old and inferior constructions continuing in general use. It is satisfactory to find, from the following abstracts from a paper of Mr. Faraday, that the course of his investigations has led him latterly to consider the deflagrator of our countryman as the most efficient form of a galvanic series. We quote those passages of Mr. Faraday's paper on the subject of the deflagrator which tend to justify our statement.

"The advantages of this form of trough are very numerous and great. 1st. It is exceedingly compact, for one hundred pairs of plates need not occupy a trough of more than three feet in length. 2d. By Dr. Hare's plan of making the trough turn upon copper pivots which rest upon copper bearings, the latter afford *fixed* terminations; and these I have found it very convenient to connect with two cups of mercury, fastened in the front of the stand of the instrument. These fixed terminations give the great advantage of arranging an apparatus to be used in connexion with the battery *before* the latter is put into action. 3d. The trough is put into readiness for use in an instant, a single jug of dilute acid being sufficient for the charge of one hundred pairs of four inch plates. 4th. On making the trough pass through a quar-

372. It was the power of simultaneously lowering or lifting all the plates attached to a beam, that caused a preference to be given to the apparatus of Babington's construction, over that of Cruikshank. Yet as it was found expedient, by Davy and others, to attach no more than ten couples to a beam, the object of an instantaneous and simultaneous immersion of the whole series in the liquid, or that of its extrication therefrom, could not be effected conveniently upon the Babington plan.

373. I succeeded in this object by various constructions, which I have designated generally as galvanic deflagrators. It may be inquired, in what respect do series thus constructed so much differ from others as to deserve a peculiar name? The reply is, that in voltaic series, as employed by its inventor, and as used by all subsequent operators, the plates were necessarily subjected to the exciting reagent in the first instance, the circuit being completed by a communication, subsequently made, between the electrodes. In that construction, to which I give the generic term deflagrator, the circuit may be completed by the simultaneous exposure of the whole series of plates to the exciting reagent, either simultaneously with, or subsequently to, the completion of the rest of the circuit.

374. Turner alleges, that an advantageous variation of this contrivance was made by Mr. Hart, of Glasgow, by which the copper was formed into a hollow parallelopiped. This construction was resorted to by me as early as the year 1822, but not finding it as convenient for filling and emptying

ter of a revolution, it becomes active, and the great advantage is obtained of procuring for the experiment the effect of the *first contact* of the zinc and acid, which is twice or sometimes even thrice that which the battery can produce a minute or two after. 5th. When the experiment is completed, the acid can be at once poured from between the plates, so that the battery is never left to waste during an unconnected state of its extremities; the acid is not unnecessarily exhausted; the zinc is not uselessly consumed; and, besides avoiding these evils, the charge is mixed and rendered uniform, which produces a great and good result; and, upon proceeding to a second experiment, the important effect of *first contact* is again obtained. 6th. The saving of zinc is very great. It is not merely that, whilst in action, the zinc performs more voltaic duty, but *all* the destruction which takes place with the ordinary forms of battery between the experiments is prevented. This saving is of such extent, that I estimate the zinc in the new form of battery to be thrice as effective as that in the ordinary form. 7th The importance of this saving of metal is not merely that the value of the zinc is saved, but that the battery is much lighter and more manageable; and also that the surfaces of the zinc and copper plates may be brought much nearer to each other when the battery is constructed, and remain so until it is worn out: the latter is a very important advantage. 8th. Again, as, in consequence of the saving, thinner plates will perform the duty of thick ones, rolled zinc may be used; and I have found rolled zinc superior to cast zinc in action; a superiority which I incline to attribute to its greater purity. 9th. Another advantage is obtained in the economy of the acid used, which is proportionate to the diminution of the zinc dissolved. 10th. The acid also is more easily exhausted, and is in such small quantity that there is never any occasion to return an old charge into use. Such old acid, whilst out of use, often dissolves portions of copper from the black flocculi usually mingled with it, which are derived from the zinc: now any portion of copper in solution in the charge does great harm, because, by the *local* action of the acid and zinc, it tends to precipitate upon the latter, and diminish its voltaic efficacy. 11th. By using a due mixture of nitric and sulphuric acid for the charge, no gas is evolved from the troughs; so that a battery of several hundred pairs of plates may, without inconvenience, be close to the experimenter. 12th. If, during a series of experiments, the acid becomes exhausted, it can be withdrawn, and replaced by other acid with the utmost facility; and after the experiments are concluded, the great advantage of easily washing the plates is at command. And it appears to me, that in place of making, under different circumstances, mutual sacrifices of comfort, power, and economy, to obtain a desired end, all are at once obtained by Dr. Hare's form of trough."

as other constructions, the parallelopipeds were laid aside, and are still in my laboratory.

375. I shall introduce into an appendix, engravings and descriptions of several forms of voltaic series to which I successively resorted. The construction to which I have finally given preference, is that of a Cruikshank trough, so modified as to increase its power, to enable it to act as a deflagrator, and render it possible to scrape the plates.*

* *Engraving and Description of a Deflagrator of Two Hundred Pairs of Fourteen Inches by Seven and a half, being one of the Members of a Pair of Troughs, both of the same size, and which may be used collaterally or consecutively.*

Fig. 13.

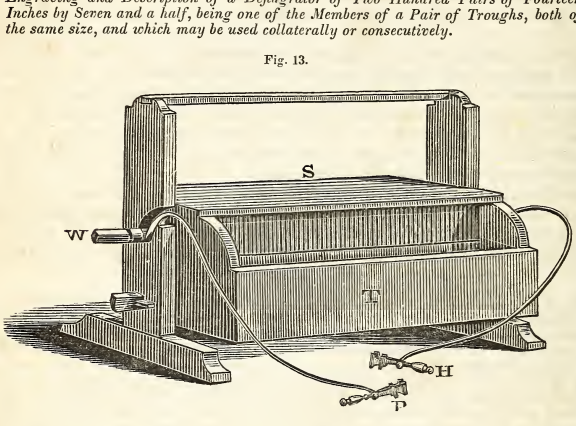


Fig. 13 represents a deflagrator. It consists of a wooden trough upon the Cruikshank plan, joined lengthwise, edge to edge, to another trough, so that when the sides of the one are vertical, those of the other must be horizontal. The advantage of this arrangement is, that by a partial revolution of both the troughs, thus united, upon pivots which support them at the ends, any fluid which may be in one trough, must flow into the other; and, reversing the movement, must flow back again. The galvanic series being placed in one of the troughs, the acid in the other, by a movement such as described, the plates may all be instantaneously subjected to the acid, or relieved from it. The pivots are made of iron, coated with brass or copper, as less liable to oxidizement. A metallic communication is made between the coating of the pivots, and the galvanic series within. In order to produce a connexion between one trough of this description and another, it is only necessary to allow a pivot of one trough to revolve on one end, and a pivot of the other trough to revolve upon the other end of a strap of sheet copper. To connect with the termination of the series, the leaden rods, to which are soldered the vices, or spring forceps, for holding the substances to be exposed to the deflagrating power, one end of each of the lead rods is soldered to a piece of sheet copper. The pieces of copper thus soldered to the lead rods, are then to be placed under the pivots, which are, of course, to be connected with the terminations of the series. The last mentioned connexion is conveniently made by means of straps of copper, severally soldered to the pivots, and the poles of the series, and screwed together by a hand-vice. Each pair consists of a copper and a zinc plate, soldered together at the upper edge, where the copper is made to embrace the edge of the zinc. The three remaining edges are made to enter a groove in the wood. For each inch in the length of the trough there are three pairs. In the series represented by fig. 13, there are one hundred pairs of nearly fourteen by seven and a half inches.

The pair of troughs, forming, when associated, a single deflagrator, of which one is represented by fig. 13, may be employed either by connecting them at their homo-

Of the different Modes in which the Power of a Galvanic Battery may be augmented.

376. Obviously there were two modes in which the power of a galvanic battery could be augmented; one was that of increasing the size of the plates of each pair, the other that of increasing the number associated as a series.

377. It has been mentioned, that under the name of calorimotor, the elementary battery or galvanic triad (312) was first made of gigantic size in this country (324). By Wollaston it had been tried in the minute form of a silver thimble, of which the cavity was occupied by a minute cylinder of zinc surrounded by a potent exciting liquid. In the calorimotor the number was reduced to unity, while the size was enormously increased, the liquid being highly energetic. In Davy's pile of two thousand pairs, the number was comparatively very large, the energy of the liquid as great as could be used with advantage. By Gassiot, the number has been carried to three thousand five hundred and twenty, excited by a liquid of no higher energy than river water.

378. In the voltaic series thus employed by Crosse and Gassiot, we see that the number of the triads is exceedingly large, while the activity of the liquid is brought down

geneous or heterogeneous extremities. When connected at their homogeneous ends, they act *collaterally* as a series of one hundred pairs of fifteen by fourteen; when connected at their heterogeneous extremities, they act *consecutively* as a series of two hundred pairs, each fourteen by seven and a half. Of course, agreeably to the first mentioned arrangement, we double the quantity, the intensity being unaltered: according to the arrangement last mentioned, the intensity is doubled without an increase of the quantity.

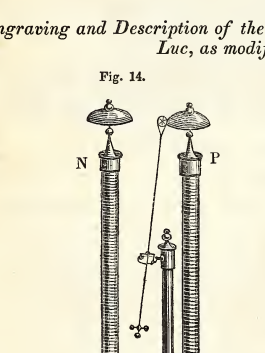
It may be proper to mention, that these Cruikshank deflagrators are so constructed, as that the plates may be scraped after each operation. Every fifth plate is cemented, so as to form a water-tight partition. As the plates are purposely so cut, as to lessen in width from the upper to the lower edge, those which are not cemented may be easily withdrawn in order to be scraped. But the withdrawal of every four moveable plates, leaves vacant spaces sufficiently large for the introduction of a tool suitable for scraping those which are not removable.

A battery of this construction was made, under my direction, for the Lowell Institute, consisting of four troughs, each containing one hundred plates six and a half inches square. A piece of wooden plank, three inches wide, thirteen inches long, and two inches in thickness, is so bored by a centre-bit as to have eight cylindrical cavities, all these being supplied with mercury. By means of ropes of copper wire, the various portions of mercury are made to communicate each with one of the eight poles of the four troughs. Arches of stout copper wire are provided of different lengths, so that, by variously connecting the mercury in the holes, the whole may be made to coöperate as one series of four hundred pairs each of forty-two inches, one series of two hundred pairs of eighty-four inches, or one series of one hundred pairs of one hundred and sixty-eight inches surface.

to a minimum, even below that of the saliva in the experiment with the tongue (306), or the sanguineous slime of the frog in the experiment of Galvani (309). But in the column of De Luc no liquid reagent is employed, since it cannot be pretended that the hygrometric moisture of the paper, entering into its construction, exists in the liquid form. This series, as originally contrived, consisted of disks of silvered paper alternated with disks of zinc as thin as possible, and each of about five-eighths of an inch in diameter. An analogous series, devised by Zamboni, consists of disks of the same size, coated on one side with leaf tin, on the other with a paste of black oxide of manganese and sulphate of zinc. According to Daniell, a series of this last mentioned construction has been made, comprising 20,000 pairs, respecting the powers of which an account will be given in due course.

Engraving and Description of the Electric Columnar Apparatus of De Luc, as modified by Zamboni.

Fig. 14.



379. Of an apparatus of the above mentioned construction, the adjoining figure is a representation. It consists of two columns, which communicate by a plate of zinc. The letters P *p*, show the ends forming the positive poles, while N *n* indicate those forming the negative poles. The anode of one, and the cathode of the other, communicating through the zinc plate, it must be evident that the columns are so arranged as to act consecutively. (See note, page 22, 2d paragraph.)

380. No doubt the electric columns owe their efficiency to that electromotive process, which, in other apparatus, causes an electric accumulation at the electrodes; but the phenomena are almost exactly those of electricity created by friction.

381. When the apparatus represented by the engraving was recently constructed, it produced sparks at every contact of the bells with the pendulum. It communicated a charge to a small coated glass cylinder, sufficient, in passing through the thumb and finger, to give a shock extending to the wrist. After it had been constructed for more than ten years, when warmed it would cause a gold leaf to vibrate between balls severally communicating with the electrodes. The

two columns comprise about 4500 disks of tinned paper, coated, on the otherwise naked side, with manganese and sulphate of zinc.*

* *On the Construction of De Luc's Columns, as modified by Zamboni; and on a Modification of the Single Leaf Electrometer contrived by the Author, by which the ultimate efficiency of a large electric series may be ascertained, by testing a small portion of the members of which it is to be constituted.*

About fifteen years ago, the construction of De Luc's electric columns, as modified by Zamboni, was undertaken by Isaiah Lukens, one of our most skilful and ingenious mechanicians.

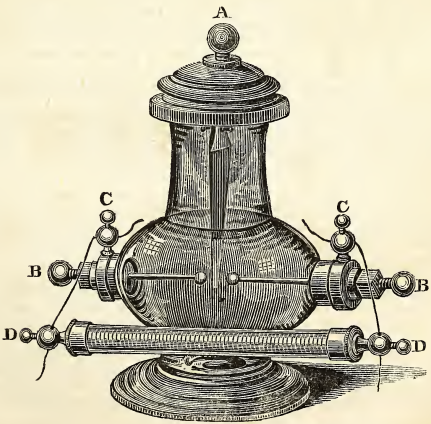
The materials employed were paper covered with leaf tin (erroneously called silvered paper), peroxide of manganese, and crystallized sulphate of zinc.

The peroxide was finely pulverized and mixed with a concentrated solution of the sulphate. The mixture thus formed was, by means of a brush, applied like a pigment to the surfaces of the paper not coated by the tin. The sheets were afterwards spread out on the floor of an apartment, and left during the night to dry. By these means, unnecessary exposure to light was avoided, which Mr. Lukens conceives to be injurious, especially as received directly from the sun. Next day the sheets were cut into disks of about five-eighths inch diameter, by means of a hollow punch. The disks were then piled, with the heterogeneous surfaces alternating, as in other voltaic series, and were introduced into, and compressed within, glass tubes, accoutred as usual with pedestals, caps, and bells. Notwithstanding his skill and experience, Mr. Lukens latterly complained of occasional want of success, arising, as he supposed, from the defective quality of the manganese. In various instances, his columns, after being constructed with the utmost care, proved inert.

The manipulation, likewise, according to his plan of operating, appeared to me to be troublesome and precarious. He was accustomed to place a row of the disks, as large as could be conveniently handled, in a trough of sheet metal, and then transfer the pile thus formed to the glass tubes. This operation, to be successful, required dexterity.

In February, 1833, wishing to replenish the tubes of a pair of electric columns which had become effete, I contrived to avoid the risk of expending the labour and attention requisite to finish a series, while uncertain as to its eventual efficiency. I

Fig. 15.



Of Groves' Gas Battery.

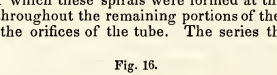
382. "In the L. and E. Phil. Mag. for December, 1842, a most extraordinary and perfectly novel voltaic battery is described by the inventor, Mr.

contrived, likewise, by a very simple expedient, to facilitate the process of piling the disks.

The first mentioned desideratum was obtained by means of a single leaf of gold, suspended in a glass vessel (represented by the subjoined figure), between two knobs at the ends severally of two brass rods, B B, proceeding through opposite sides of the vessel towards each other, so as to be capable, if requisite, of meeting in the centre. By means of screws, the knobs on these rods were susceptible of being adjusted to any distance from the gold leaf suspended between them. Externally the rods are so made and placed, as to be easily connected with wires. In the gold leaf thus situated, vibrations may be produced by a series of disks, comprising not more than one-twentieth of the number necessary to cause such a pendulum as commonly pertains to the electric column, to oscillate. In the case in point, I found that the disks produced by one sheet of paper, were sufficient to make the leaf vibrate actively between the knobs. The mode in which this effect was produced, may be understood from the following figure, which represents the disks, as compressed, in due order, within a glass tube, by spirals of wire.

Each of the wires of which these spirals were formed at the ends enclosed in the tube, being unaltered throughout the remaining portions of their length, were passed through corks closing the orifices of the tube. The series thus prepared, is to be

Fig. 16.



placed in the situation of the electric column, appended to the instrument agreeably to fig. 15, being in like manner suspended from the rods outside of the vessel, by means of the projecting wires already mentioned. Thus situated, if there be any adequate degree of electromotive power in the series under trial, and the atmosphere sufficiently dry, the excitement of the poles will be communicated to the knobs, and be indicated by the consequent vibrations of the gold leaf suspended between them.

When a larger series is used, such as that represented at D D, fig. 15, the vibrations will be discontinued, only in consequence of the adherence of the leaf to one or the other of the knobs. This adherence usually ceases, on touching with a finger the little brass ball at the vertex of the instrument, to which the forceps holding the leaf is affixed. The finger being removed, vibratory pulsations will recommence, to be sooner or later arrested in the same manner as at first.

When the knobs, B B, were properly connected with the poles of a voltaic battery, of seven hundred pairs, excited merely by pure water, the pulsations of the leaf were quick and incessant. These pulsations may indicate the electric intensity, but do not furnish any criterion of the divellent igniting, or electro-magnetic powers of a voltaic series.

It may readily be perceived, that the electrometer, constructed as herein described, constitutes an electrical discriminator, which may enable us to discover the electromotive powers of various substances arranged as disks in a series, or as coatings to disks. I have already ascertained that aurum musivum, spread on the naked surface of the tinned paper, produces an electromotive series.

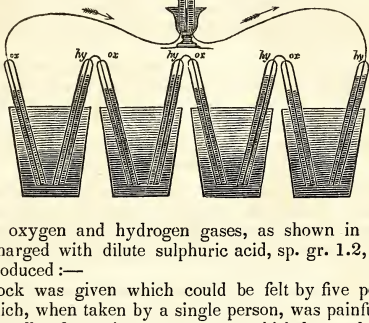
The piling of the disks was facilitated by using a punch excavated so as to leave a point in the centre, by which the centre of each disk was punctured. By means of the puncture thus made, it was easy, even for an unskilful operator, to string them concentrically upon a silk thread, and to transfer them to the tubes without derangement.

The manganese which I employed with success, in the replenishment of the electric columns alluded to above, consisted mainly of needle-shaped radiated crystals, aggregated into lumps. Mr. Lukens alleges that the crystallized manganese has always, agreeably to his experience, proved the best for the construction of electric columns.

The electrometer, with an electric column attached to it, as above represented,

Grove. It consists of a series of fifty pairs of platinized platinum plates, each about a quarter of an inch wide, enclosed in tubes partially filled, al-

Fig. 17.



ternately with oxygen and hydrogen gases, as shown in fig. 17. The tubes being charged with dilute sulphuric acid, sp. gr. 1.2, the following effects were produced:—

"1st. A shock was given which could be felt by five persons joining hands, and which, when taken by a single person, was painful.

"2d. The needle of a galvanometer was whirled round, and stood at about 60°; with one person interposed in the circuit it stood at 40°, and was slightly deflected when two were interposed.

"3d. A brilliant spark, visible in broad daylight, was given between charcoal points.

"4th. Iodide of potassium, hydrochloric acid, and water acidulated with sulphuric acid, were severally decomposed: the gaseous elements from the decomposed water were extricated in sufficient quantity to be collected and detonated. They were evolved, as chemical theory and experience would indicate, the hydrogen at the anode, the oxygen at the cathode. It was

may serve to show the nature, as well as the extent of electric excitement; since, when an electrified mass is made to communicate with the brass ball, A, from which the leaf is suspended, the latter ought to be attracted by that knob, which receives from the series an opposite excitement. Hence, the excitement of the electrified body being known, that of the poles may be detected: or the latter being known, the excitement of the body may be discovered. This application of the electric series is not, however, a new idea. I saw many years ago a notice of an electrometer, associated with an electric column, in such manner as to be used as an electrical discriminator.

The great difficulty in resorting to this means of discrimination is, that an electrified body may, by induction, produce in a conductor alternately, opposite states of electrical excitement. As it approaches the conductor, it may cause it to receive, or give out electricity; of course, when retracted, the conductor will have the opposite excitement to that consequent to approximation. Supposing the brass ball of the electrometer in question, to be affected in the mode just described, the leaf suspended from it must be successively attracted by each pole. Besides, the excitement may be so strong, as to render that of the series nugatory; as in the case of a powerful magnet, which will attract either pole of a feeble one.

The direction of the first pulsation of the leaf is the best criterion; but reliance should not be accorded to one experiment, especially when so easily repeated. I find that a gilt pith ball, if suspended in place of the leaf, will vibrate for a time. It is, however, like the leaf, liable to have its movements arrested by an adherence to one or other of the knobs.

found, that to decompose water, twenty-six pairs were requisite, but that four pairs would decompose iodide of potassium.

"5th. A gold leaf electroscope was perceptibly affected.

383. "When the tubes were charged with atmospheric air, no effect was produced, nor was any current determined when the gases employed were carbonic acid and nitrogen, or oxygen and nitrogen.

384. "The original experiment was not made with sufficient exactness to show with accuracy the proportional diminution of gas in each tube, though it was plain that the hydrogen diminished much more rapidly than the oxygen."

385. The electrodes are represented as terminating in tubes for catching the gaseous elements of water, evolved by the electrolytic power of the same elements, under the electro-polarizing influence of platinum.

Of the Electrolytic Process by which the Galvano-Electric Current is propagated within Liquid Reagents.

386. Before giving an account of these forms of the galvanic series, in which more than one chemical reagent is employed, it may be expedient to enter more fully into the rationale of that part of the galvanic process by which the electric fluid is supposed to be transferred from the zinc to the copper, through the exciting liquid.

387. Faraday assumes, that the fundamental cause of the hydro-electrical current, or that produced by the reaction of metals with liquids, is chemical affinity between one of the metals employed and an ingredient in some electrolyte contained in the liquid, and that the combination of an atom of the metal with an ingredient atom, taken from the liquid electrolyte, causes an equivalent discharge of electricity from the atom so taken.

388. Thus, when zinc combines with the oxygen of water, performing the part of an electrolyte, a discharge of electricity from the atom of oxygen is a necessary consequence. Hence, in some cases, as, for instance, that of pure zinc exposed to diluted sulphuric acid, unless the requisite discharge be facilitated by contact with a metal not capable of combining with oxygen, no combination ensues. But, under the same circumstances, if, while the oxygen of the liquid is attracted by zinc, the liquid be in contact with a plate not liable to be oxidized by it, the discharge of electricity is facilitated, as soon as a conducting communication is established between the metals. He supposes a series of decompositions and recompositions to take place within a row of the particles of water lying between the zinc and copper surfaces, so that the atom of oxygen next the zinc surface, uniting with an atom of this metal, discharges its electricity to the next atom of hydrogen, which unites with the oxygen of the next atom of water. But in doing this, it causes the transfer of its electricity to the third atom of hydrogen. This process being repeated, an atom of hydrogen surcharged with electricity, is evolved against the copper surface. Hence the surcharge acquired by the copper goes through the connecting wire, to restore the electrical tension within the zinc which the chemical reaction tends to diminish as above stated.*

* If we suppose, in a dance, a number of girls and boys standing in a row, in couples, alternately arm in arm, alternately separate, and that a girl is suddenly taken from one end of the row, and a boy from the other end, evidently of each sex there would be an individual isolated. But if, simultaneously, each girl relinquishing her hold on the partner of which she had the arm previously, takes that of the next boy on the other side, there will be no individual of either sex in a solitary state.

389. The idea that the appearance of hydrogen at one electrode, and oxygen at the other, is the effect of a series of decompositions and recompositions, as above stated, was originally suggested by Grothus, as accounting for the fact, that the extrication of hydrogen and oxygen from electrolysed water does not take place at the same spot. It had been objected that it was inconceivable that the elements of water, arising from the decomposition of a succession of atoms of this liquid, could be severally evolved at the distance of some inches from each other.

390. In the last edition of my Treatise on Galvanism, after having cited the electrolytic theory of Faraday, (386, 387,) I subjoined the following remarks:—

391. Whatever may be the source of the imponderable matter which circulates in voltaic series, I infer, that its confinement within the circuit, and its endowment with an ability to pass over an interval, or to penetrate through imperfect conductors, must be due to an influence of the masses concerned, which has not as yet been satisfactorily explained.

392. Probably upon an analogous ability to produce or annul, to promote or retard, chemical reaction, the efficacy of animal and vegetable organization is founded, being obviously dependent on an arrangement of masses. The voltaic series of a gymnotus is evidently an animal organ, and its analogy with the voltaic series, produced by human ingenuity, induces me to consider the latter in the same class of agents as the organs by which life is supported.

393. The opinions thus expressed by me have, I think, found much to justify them in the facts established by means of Groves' gas battery. In that apparatus, a portion of hydrogen performs the part of zinc, while oxygen performs the part of copper (314). These gases exercise chemical affinity neither with water nor with platinum. An electro-polarizing reaction with the platinum is evidently the only imaginable cause for the union of an atom of gaseous hydrogen with the oxygen of water, at one of the terminating surfaces of that liquid, while, analogously, an atom of gaseous oxygen combines with hydrogen at the other aqueous surface.

394. It appears to me, that precisely the same change must ensue in the electro-polarity of the gaseous atoms during this electrolytic process, as when a mixture of the gases employed, is made to combine by the presence of platinum sponge.

395. But whatever may be the rationale, the phenomena of this gas battery, as well as those previously used, all tend to confirm the fact, that what is called the electric current, in its passage in a galvanic triad from the electropositive surface to the electronegative surface through the liquid, is inseparably associated with a series of decompositions and recompositions.

396. This electrolytic exchange of partners, in rows of atoms which, within the battery, appear to be concerned in the generation of the current, seems, externally, to be one of its effects; so that the evolution of the elements of an electrolyte, severally at the cathode and the anode (358), are ascribed to a series of decompositions and recompositions, like those which accompany the generation of the current.

397. The impression seems to exist among many electricians, judging from their language, that the elements actually travel from one electrode to the other. The choice of the word *ion*, from *io*, to go, (360) is in this respect disadvantageous. In point of fact there can be no such locomotion. Simultaneously with the liberation of an atom of each ingredient at the poles, the residual ions in the electrolytic row, rearrange themselves so as

still to form atoms of the electrolyte. Of course, a greater or less number of the electrolytic atoms will be simultaneously decomposed, out of as many rows existing in due contact with the electrodes; but it cannot be reasonably supposed, that there is not a change of relative position too incessant to permit the electrolytic process to take place twice through precisely the same row of atoms. Probably the loss of an atom can never arise from the interposition of precisely the same residual atoms which have existed once together in a row long enough to lose one atom from among them. As reasonably might a sportsman expect to find in a numerous flock of birds while wheeling about him, the same individuals twice in a line with his rested fowling piece.

398. Between the galvanic batteries above described, in which only one liquid is employed, and those constructed with the aid of two liquid chemical reagents or electrolytes, as in the case of the series of Daniell or Grove, there is this striking difference, that, in the requisite series of decompositions and recompositions, the part performed by hydrogen as the electropositive element on one side of an interposed diaphragm, is on the other performed by copper, nitric oxide, or some other radical more ready than hydrogen to separate from oxygen. The porous diaphragm soaked with sulphate of copper or nitric acid, presents throughout the whole of its area an oxidizing surface which coöperates with the opposite influence of the deoxidizing zinc to effect the disunion of the elements of water. Hence while the electrolytic exchange is solicited on one side, by the attraction of zinc for oxygen, it is solicited on the other side by the attraction between hydrogen and the oxygen of the other electrolyte with which the pores of the diaphragm are imbued. In nitric acid, nitric oxide, acting as a compound radical, performs the part of the simple radical copper, in the oxide of this metal held in the sulphate. The liberation of one atom of nitric oxide, at the surface of the platina, causes three atoms of oxygen to be yielded to the hydrogen of water at the membrane, more readily than an atom of copper, analogously liberated, causes one atom of oxygen to be yielded. This I conceive to be the main cause of the superior efficacy of Grove's nitric acid sustaining battery, of which a description is given in the following pages. To the advantage thus gained is to be added that of the protection of the metallic surfaces from injurious deposition (315).

Of Constant or Sustaining Batteries.

399. In the year 1835, Prof. Daniell, of King's College, London, made an interesting and important innovation in the construction of galvanic batteries, by the interposition of an animal membrane, the gullet of an ox for instance, between the heterogeneous metallic surfaces. A battery of this kind in my possession, consists of a cylinder of copper, about six inches in height and four inches in diameter. Within an inch and a half of the brim, a diaphragm of copper is inserted. This diaphragm is perforated like a colander, and has, at the centre, a hole of about an inch and a half in diameter. It is through this hole that the gullet is made to descend to the bottom of

the vessel, where it communicates with a glass tube, which is so bent at right angles twice, and so extended as to rise by the side of the cylinder and terminate in a recurved orifice on a level with the brim. A solid cylinder of amalgamated zinc, of half an inch in diameter, is made to occupy the cavity of the gullet.

400. It has already been mentioned, that in this construction, the copper is not liable to be tarnished nor the zinc to be coated by a deposition,* and thus to be rendered incapable of their appropriate reaction with the interposed liquid. The membrane will not allow a solution of either metal to permeate it, although it permits the transmission of the electro-chemical decomposition and recomposition, by which the voltaic current is sustained. The space between the gullet and the cupreous surface of the enclosing cylinder, is occupied by a saturated solution of sulphate of copper, the cavity within the gullet by diluted sulphuric acid, or some saline solution not liable to be decomposed, *per se*, by zinc. Upon the diaphragm, crystals of sulphate of copper are deposited, for the purpose of preventing any decline in the strength of the solution of that salt. As the diluted acid employed becomes saturated with zinc, it is displaced by a fresh portion which causes that first mentioned to be expelled at the orifice of the glass tube. Of course, the chemical reaction may be kept up as long as the zinc lasts. Latterly, in the construction of Daniell's battery, the glass tube has been omitted, as the advantage arising from its employment, has not been found to compensate for the additional liability to derangement.

401. I saw at the laboratory of Prof. Daniell, an association of his sustaining batteries, of which the power to ignite wire was surprising.

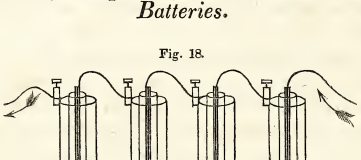
402. According to Brande, with a constant battery of twenty cells arranged in a single series, twelve cubic inches of mixed hydrogen and oxygen may be collected in every five minutes of action; and, when they are connected in pairs and afterwards in a series of ten, the quantity amounts to seventeen cubic inches. Eight inches of platinum wire, one two-hundredths of an inch in diameter, may be kept permanently hot by the same arrangement, and the spark

* The deposition thus formed consists of a mixture of copper and suboxide of zinc (315, and note).

taken between charcoal points is very brilliant. To the original form of Daniell's battery above described, there is however, a great objection, founded on the employment of an animal membrane, which is of course liable to be injured or spoiled. Porous vessels of unglazed earthenware have been, however, substituted for animal membrane with great increase of convenience, and they are now employed both in this and other forms of voltaic apparatus. Leather has also been successfully substituted for raw membrane.

Engraving and Description of a Voltaic Series of Constant Batteries.

Fig. 18.



403. The preceding figure will convey a sufficient conception of a sustaining battery, in which cylinders of porous porcelain are substituted for the ox gullet employed agreeably to the original construction of Daniell's apparatus.

404. The external lines represent sections of round copper jars, the dark central lines represent the amalgamated zinc rods, situated in the common axis of the copper jars, and of the cylinders of porous porcelain. These are represented as occupying a mean position between the zinc and copper. The charge of the apparatus and rationale of its operation, is the same as that already stated in reference to the constant battery in its original form.

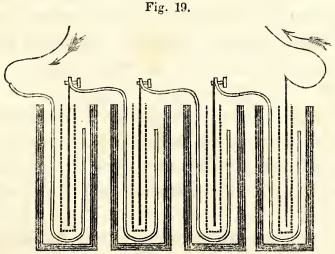
405. I do not believe the effects of any apparatus constructed upon this plan, to be at the outset as powerful or striking as those which are producible by a deflagrator of a like extent of surface. Still less would it be possible to comprise a series of like degree of power within a space equally small. A series of two hundred pairs of sustaining batteries would be extremely unwieldy and cumbrous. It

has been mentioned that the construction of the deflagrator is such, as to enable me to withdraw four plates out of every five, so as to have the whole accessible to a scraper. Moreover, the amalgamation of the zinc surfaces, devised by Sturgeon, confers upon the plates of the Cruikshank construction, to a certain extent, the properties of a sustaining battery. The great objection, to the somewhat costly use of mercury, is, that it enfeebles the zinc plates so as to make them liable to fracture; but this is less to be apprehended when the zinc is supported by corresponding copper plates, as in pairs of the kind above designated, and where the mercury, as in these pairs, is to be applied only to one of the surfaces of each zinc plate.

Of Grove's Sustaining Battery.

406. About the year 1840, Prof. Grove made a very interesting modification of Daniell's battery, not only by substituting vessels of porous porcelain for the ox gullet, but also by using platinum and nitric acid in lieu of copper and a solution of the sulphate of that metal. The porous cell, nearly full of nitric acid, is surrounded by zinc immersed in sulphuric acid diluted with only four parts of water, contained in a sufficiently capacious receptacle. The nitric acid, by oxidizing the hydrogen, accelerates the electrolysis, nitric oxide is evolved at the surface of the platinum, which is made to occupy an intermediate position within the porcelain cell.

Fig. 19.



407. The dark central lines (figure 19) represent sections of the platinum plates; the dotted lines C, which include these, represent the hollow cylinders of porous por-

celain. The double lines, which comprise both of those already mentioned, represent sections of the zinc cylinders. The dark external lines, in like manner, represent the glass jars within which the rest of the apparatus is situated. The arrows indicate the course of the current flowing externally agreeably to the general law, from the metal less susceptible of erosion, to that more susceptible; while conveyed internally by the electrolytic process, it takes the opposite course so as to complete the circuit. (306).

408. A series of this kind of only four pairs, constructed in my laboratory, caused the long continued ignition of about two inches of platinum wire. According to Prof. Grove, a series of one hundred pairs, each of the same dimensions as those above described, caused a diruptive discharge, accompanied with intense heat and light, through an interval of three inches, which is as much as was effected in this way, by the great battery of two thousand pairs with which Davy operated at the Royal Institution.

409. Latterly it has been found that plumbago or coke may be substituted for platinum in Grove's apparatus. This material was resorted to independently both by some German chemists, by Prof. B. Silliman, Jr. and myself. An extensive series was constructed for the Lowell Institute, by Prof. B. Silliman, which was very powerful, and had the advantage over the deflagrator of a much more durable intensity of action. In practice, however, there are several objections to Grove's apparatus. The separate introduction of sulphuric and nitric acid into a great number of receptacles in a much more concentrated state than that in which they are used for other voltaic series, as well as the subsequent removal, is a very troublesome and disagreeable task. Moreover, the fumes of nitric oxide which are copiously evolved, are extremely annoying to all persons exposed to them, and are to some persons insupportable. The porcelain cells are very liable to be broken, and soon suffer by the disintegrating influence of the acids.

410. In an arrangement suggested by Berzelius, a cylinder of coke is hollowed out into the form of a cup, into which the nitric acid is placed, and thus the use of an earthenware diaphragm is avoided.

411. A great difficulty arises from the expensive neces-

sity of employing platinum as the material of the screws and wires, by which the requisite attachments are made in batteries formed by the aid of carbon, as above described. Any other metal, excepting gold, which is three times as dear as platinum, is liable to be corroded by the nitric acid, which rises in the carbonaceous pores, by capillary attraction.

Of the Passive Iron Battery.

412. The battery thus designated, was first suggested by Mr. Hawkins (L. and E. Phil. Mag. Vol. XVI.), in consequence of the previous discovery by Herschell, Schoenbien, and others, of the susceptibility of iron of what is called the *passive* state, which renders it insusceptible of being acted upon by strong nitric acid; whereas, in its ordinary state, it is oxidized and dissolved in that acid. The passive state does not protect the metal from acid of the s. g. 1.2. This state of iron is induced by the contact or association with platina, of which, being highly electronegative, the presence by analogy with copper and zinc should promote reaction with corroding reagents (321). The passive state also protects iron when exposed to diluted sulphuric or phosphoric acid, but cannot avail against chlorohydric acid.

413. This phenomenon is one of the most mysterious, but it is not expedient now to enter into any discussion respecting the cause. The object is to mention the use made of this wonderful property. As the inactive condition is spontaneously assumed when iron is plunged into acid of s. g. above 1.35, a plate of this metal has been substituted in a Grove's battery for the platina plate. According to the authors above named, batteries thus formed were found to be efficient; but, unfortunately, the peculiar condition of the iron is liable to cease. When this happens, the rapid solution of the negative plate follows.

414. Schoenbien mentions the formation of batteries either of zinc and passive iron, or altogether of iron cylinders, one set being passive, the other in the normal condition. Five cast iron cylinders, 10 inches high, $3\frac{3}{7}$ diameter; as many of zinc of same height, and $3\frac{3}{12}$ in diameter. Intermediate between the zinc and iron, porous cylinders of earthenware, one part nitric, s. g. 1.4, with from twelve to three parts sulphuric acid, were found to

answer. Subsequently, cylinders of iron, in its ordinary state, were substituted for zinc cylinders. By this battery, 2400 cubic inches of the gaseous elements of water were liberated in one hour.

415. It seems, however, that the passive condition of iron is liable to cease, and when this happens, the metal is dissolved. I am under the impression that batteries of this kind can never be found advantageous, as, independently of the uncertainty arising from the precariousness of the passive state of iron, this metal is very liable to be injured by rust when out of use.

Of Smee's Battery.

416. About six years ago, Mr. Smee, of London, discovered that the efficacy of a battery, made like calorimotors or deflagrators (324, 375), Babbington's apparatus, (367), or one of his own contrivance, in which a thin sheet of silver is situated between two plates of zinc, may be augmented by a deposition of platina sponge being made upon the surface of the negative metal. For this purpose, platina, palladium, silver, or plated copper, may be used; but, taking both efficacy and economy into view, silver, rolled very thin, was found preferable.

417. In the case of a constant or sustaining battery, (398) it has been stated that the oxidizement of the hydrogen at the diaphragm, obviating the necessity for its evolution in the gaseous form at the cathode, facilitates the electrolytic part of the electromotive process in a galvanic circuit. In Smee's apparatus, the extrication of the hydrogen at the cathode, is alleged to be facilitated by the mechanical power of the asperities of the platinizing deposition. I infer, however, that the contact of the platinum may have a favourable polarizing influence on the hydrogenous cathion, promoting its separation from the other element of water, analogous to that exercised by the same metal in the gas battery (393–4).

418. The following directions are given for platinizing the plates: "Each piece of metal is to be placed in water, to which a little dilute sulphuric acid, and nitro-muriate of platinum, is to be added. A simple current is then to be formed by zinc placed in a porous tube with dilute acid; when, after the lapse of a short time, the metal will be

coated with a fine black powder of metallic platinum. The trouble of this operation is most trifling, only requiring a little time after the arrangement of the apparatus, which takes even less than the description. The cost is about 6*d.* a plate, of 4 inches each way, or 32 inches of surface. It is necessary to make the surface of the silver rough, by brushing it over with a little strong nitric acid, which gives it instantly a frosted appearance, and after being washed, it is ready for the platinizing process; but the finely divided platinum does not adhere firmly to very smooth metals."

OF THE PHENOMENA OF GALVANISM.

Under this head we may put effects upon the animal organs, statical effects, ignition of continuous conductors, deflagration, electrolysis or decomposition, galvanic powers and effects of animal organs, magnetic influence or electro-magnetism, galvanic effects of heat, or thermo-galvanism, sometimes called thermo-electricity, or thermo-magnetism.

EFFECTS UPON ANIMAL ORGANS.

Effects on the Organs of Taste, on those of Sight, Nerves of Sensation; in producing Convulsions.

419. Electricity is not the only one among the supposed imponderable elements, which can cause sensation. The influx and efflux of caloric produces a sensation in one case of cold, in the other of heat; moreover intense light, like that of the sun, of galvanic ignition, or the oxyhydrogen lime light, produces in the eyes a painful feeling. But in giving shocks to live animals, and in causing muscular movements or convulsions in a carcase or corpse, electricity has a peculiar attribute.

420. Probably the first knowledge of the shock produced from a galvanic circuit, arose from experiencing that given by the torpedo and other electrical fishes. This wonderful faculty could not but have been observed in the most ancient times by fishermen in the countries where such animals are found.

421. A very feeble discharge like that between a zinc and silver disk, including the tongue, has been felt from the

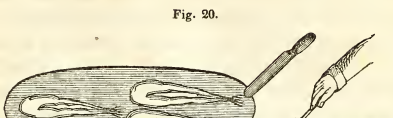
earliest period at which wine, cider, or beer of any kind, was drunk from a metallic vessel. The preference given to pewter as the material of a mug from which to drink beer, is now ascribed to a galvanic discharge arising from the metal, the lips and the beverage, forming a feeble galvanic triad, in which the liquid is electropositive, being slightly acidulous. Probably from an analogous cause arises the characteristic taste of acids, while from an opposite galvanic discharge in which the solution is electropositive, arises the peculiar savour of the principal alkalies. I am inclined to the idea that all the various tastes and odours, which we are liable to experience, are due to modifications of galvano-electro-chemical causes.

422. But the first recorded notice of the phenomena of a galvanic discharge, as respects its obvious production by a metallic triad, was published not as associated with a theory directed to the explanation of physical phenomena; but on the contrary, in a metaphysical effort to suggest a theory of pleasures. In the year 1767, more than twenty-three years before the convulsions produced in frogs by metals was noticed by Galvani, Sultzer, the author of the theory of pleasures alluded to, gave an account of the taste produced by heterogeneous metals, when including the tongue, and brought into contact at their projecting extremities.

423. It must be evident that the original observer of the phenomenon, thus described by Sultzer, was the discoverer of the elementary galvanic battery; and it is remarkable that Galvani was led to infer the existence in nature of the powers of such a battery, by a phenomenon which had no connexion therewith. The hind parts of the carcases of some frogs, prepared for stewing, happened to be situated in a dish, one of them in contact with a scalpel, near an electrical machine, from the prime conductor of which sparks were proceeding. Under these circumstances it was observed, that every spark was followed by convulsive motions in the limbs in the vicinity of the scalpel. The effect was greatest in any limb to which the scalpel might be most approximated. The annexed figure will convey an idea of the manner in which the frogs were situated, relatively to the scalpel; and likewise to the conductor of the machine and knob, between which the sparks were thrown. Galvani was absent, and was in-

debted for his knowledge of the fact to Madam Galvani, by whom it was noticed.

Fig. 20.



424. The convulsions thus observed, it is now known, were the consequence of the limbs and the scalpel being inductively electrified. It is by an analogous inductive influence, that when one person is struck by lightning, bystanders are stunned, though not in the circuit. Electrical discharges deleterious to human life have been attributed to an inductive charge and discharge consequent to lightning, and analogous to those which convulsed the frogs. (See Dynamic Induction.)

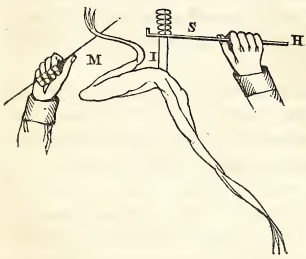
425. Galvani having been previously engaged in the experiments, to verify a conjecture of his, that muscular action is due to electricity, became inspired with additional zeal by these facts, for a knowledge of which he was indebted to accident and his wife's observation. Nevertheless, he would have attributed little importance to the convulsions produced in the frogs, had he not erroneously supposed that the animal organs were instrumental in the generation of the electricity by which they were affected.

426. But, as already stated, (309) the limb of a frog, with the spinal nerves denuded, is a most sensitive galvanoscope, since the minutest discharge of electricity through a circuit of which the nerve forms a part, will produce convulsions in the rest of the limb. Of course during their exposure to the alternate charging and discharging of the machine, the frog limbs acted merely as galvanoscopes.

427. It was, however, subsequently ascertained by Galvani, that convulsions ensue, on making a conducting communication by a metallic wire between the feet of a frog and a portion of the spine appended thereto by the denuded nerves (309). This he correctly ascribed to a power in the parts of the animal to generate electricity;

but erroneously supposed that there was any analogy between the mode of its previous existence, and that of the charge of a Leyden phial. This view of the subject was not unreasonable at a period when no knowledge had been obtained respecting the electrolytic process, by which the current in a galvanic circuit is generated. But the investigation was rendered complicated and perplexing, by the fact, that galvanic discharges causing convulsions are producible in three different ways, of which only the last described is due to the animal organs. Now, it is known the leg of a frog may be convulsed, not only as above described, by a *metallic* communication between the spinal nerve and the feet, but likewise by bringing those parts into contact without the intervention of a metal.

Fig. 21.



428. Figure (21) will illustrate the mode by which the leg of a frog being made to touch the spinal nerve, convulsions will ensue in consequence of an inherent diversity as respects electropolarity in the different parts of the animal.

429. The dissected frog limbs are suspended by means of a glass rod, H, held by the hand at one end, while the other is situated between the two partially denuded nerves of the spine, a portion of the latter, *s*, which is retained, serving to keep them united. By means of another glass rod, M, one of the legs is brought at I, into contact with a nerve. By these means the limbs may be sensibly convulsed. The previous immersion of the limbs and nerves in brine, is recommended by Sturgeon, as rendering success more attainable; but there seems to be some objection to the assistance of an inorganic reagent in an experiment intended to prove that the organs employed are *per se*, equivalent to a galvanic triad or elementary battery: it is nevertheless certain that much more active convulsions may be produced by the discharge from the most minute galvanic triad or the smallest spark arising from the friction of an electric (E, 211). Where a prepared frog is made, like the tongue in the experiment of

Sultzer, to perform the office of the liquid reagent in a galvanic triad such as above mentioned, the slime of the animal takes the place of the liquid, and the muscles included are convulsed by a discharge analogous to that by which the tongue is affected by the appropriate sensation.

430. Resting his inferences upon the superior efficacy of extraneous sources of electricity, Volta succeeded in creating an almost universal impression, that the idea of a current originating in the organs of frogs had been erroneous. This impression was strengthened by the, subsequently discovered, surprising energy of his inorganic pile in effecting ignition and chemical decomposition.*

Of the Diversity in the Sensations produced in the Human Frame by variations in the size and number of the Galvanic Pairs employed.

431. The different modes, as respects size and number, in which galvanic apparatus may be diversified, has been alluded to. It was soon found that the shock given to the animal frame was increased more by the number, than by the size of the plates. I have found the shock from two hundred and eighty triads, each two inches square, more severe than from one hundred, nearly eight by fourteen or sixteen times as large. The sensation from the latter is more excruciating, if the contact be sustained, because the quantity is so much more copious; but after repose, the poles of the more numerous but smaller series becomes as much greater than the other as twenty-eight is to ten. This greater intensity enables the charge to act more suddenly, and thus to produce the jerking sensation, usually called a shock, in a much higher degree. Davy mentions that severe shocks were received from his large pile through the floor upon which it rested. I have experienced shocks in like manner, when the floor on which a series of three hundred pairs rested, was wet.

* Under these circumstances, injustice has been done to Galvani, by designating the branch of science originating in his investigations as voltaic electricity. In Ure's Chemical Dictionary, so much of the phenomena of this branch as are associated with experiments on recent carcasses, whether of cold or warm blooded animals, are treated of under the head of galvanism, while the other phenomena are treated of under that of voltaic electricity. It appears to me, that galvanism or galvanic electricity, should be known under the general appellation, and that sufficient justice will be done to the other celebrated inventor, if we speak of the compound circuit, as the voltaic series, pile, or battery. The appellation, voltaic series, seems to be preferable, being most descriptive, since whatever may be its construction, it must consist of a *series* of elementary batteries.

432. Even with closed eyes an ideal flash of light is produced in the Sultserean experiment. According to Sturgeon, it is best executed when one of the pieces of metal employed is pressed close upon the gums beneath the upper lip, the other on the tongue. This preparation being made, a flash is produced by bringing their extreme edges into contact. To enhance the effect, the application of brine to the tongue is recommended. It should be understood that the taste endures so long as the contact continues, but the affection of the optic nerve and the slight quivering of the tongue are transient effects, attendant on the peculiar intensity of the discharge which takes place when the circuit is first completed.

433. To a cut sufficiently deep to draw blood, the most feeble galvanic discharge is perceptible; and that of an extensive battery is excruciating. On the back of the hand, from the comparative delicacy of the epidermis, and the superior conducting power of the veins, the sensibility to galvanic discharges is much higher. Moistening the skin, more especially if any saline solution be employed, causes such discharges to be much more difficult to bear. One of the best modes of taking the shock is to connect each electrode with a cup of mercury covered by water. Dipping a finger of the right hand in one, and of the left in the other, the shock will be felt in perfection. However large the plates of a voltaic series, they cannot produce any perceptible effect until the number of them, made to operate on a conductor, is sufficient to cause a discharge through it. Hence, they may cause the deflagration of a wire, when they cannot give a shock to an animal nor decompose any chemical compound. When a number competent to effect a passage is employed, the shock is not as much greater in proportion to the size of the plates as might be expected, just as in passing a needle through a muscle, our suffering would not be much increased, although, by doubling the diameter of the instrument, we should quadruple its bulk.

434. The sensation created by a comparatively small number of large pairs is more incessant, less jerking, and becomes intolerable from a sensation like the boring of a hot iron. This burning sensation is not surprising, when it is considered that fluids grow hot under the influence of such a series. In 1839, I assisted in some experiments on

the corpse of a recently hanged murderer, of whom the muscles of the face and those on which respiration is dependent, were made to act. I then observed that ignition took place whenever the lifting of the end of either wire acting as an electrode, caused an interruption of the circuit. The series employed was a deflagrator of three hundred pairs of seven by three.

Of the Statical Effects of Galvanism.

435. It will be well to remember, that under this designation are placed those phenomena of galvanism which, although extremely feeble as to comparative intensity, still resemble the phenomena of frictional electricity as respects the spark, the separation and approximation of light bodies, and the charging of the Leyden phial.

436. Of all the phenomena of galvanism, only those of a statical kind are to be produced when the circuit is incomplete; and it is under these circumstances, and others which are inconsistent with the other powers, that those in question appear to most advantage. It is only on breaking contact that galvanic apparatus, in the usual forms, will produce a spark. If we attach a metallic mass to one pole of a galvanic battery, and after bringing into contact with it the end of a wire, rod, or strap of metal, in due connexion with the other pole, suspend the contact, a spark ensues; yet none can be perceived on renewing the contact.

437. Sparks arising from the rupture of the circuit are advantageously seen, by attaching to one of the electrodes a rasp or a rachet wheel, which is so situated as to touch a spring strap in due connexion with the other electrode. By scraping the rasp with the strap, or if a rachet wheel be used, causing it to revolve against the strap, a spark occurs as often as the strap passes from one tooth to another. The spark may be produced by metals, which, like gold and platinum, are difficult to oxidize, but is larger and more brilliant when iron, steel, or mercury, is used. Of these metals, minute portions are mechanically abraded, the combustion of which coöperates in the production of intense light and heat.

438. The phenomenon which, when produced by the puny apparatus of man, we call a spark, is designated as

lightning, when evolved by the gigantic apparatus of nature. In no respect are the powers of galvanic batteries more discordant with those of electrical machines than as respects the spark. By electrical machines of the largest size, sparks of from twenty inches to two feet have been emitted: from a very small one, they may be obtained sometimes two inches in length; yet, *before* contact, the most powerful voltaic batteries could not, by the most ingenious and skilful efforts of Gassiot, be made to give any spark; and, according to Davy, the battery of the Royal Institution, comprising thirty-two thousand square inches of zinc surface insulated by porcelain, did not give a spark at a greater distance than one-fortieth of an inch (368). It follows, that to give a spark at ten inches, or four hundred times as far, would require a striking power which would be to that of Davy's series as the square of four hundred to that of one; so that the striking power of a machine giving such a spark must be one hundred and sixty thousand times as great as that of the celebrated battery above mentioned.

439. With insulated voltaic batteries of 1626 pairs made by Crosse, and of 3520 pairs made by Gassiot, excited by river water, sparks were obtained before contact. From the last mentioned battery we are informed that a current of them was obtained. The other powers of the battery are enfeebled, in proportion as its statical power is strengthened.

440. An engraving and description has been given of the dry pile of De Luc, as modified by Zamboni. According to Daniell, when a wire proceeding from one pole, of a pile of 20,000 pairs, was drawn lightly over a varnished metallic surface communicating with the other pole, a series of minute sparks were obtained. A Leyden battery might be so charged as to produce a disagreeable shock extending to the elbows and shoulders (378).

441. It does not appear to me that sufficient consideration has been given to this form of voltaic apparatus by the advocates of the purely chemical origin of the galvanic current. Faraday, the, matter of fact, Ajax of that corps, insists on the necessity of a species of electrolytic convection, between the zinc and copper surfaces, to the conveyance of the current. He urges the necessity of a process like that which is supposed to take place during the decompo-

sition of water between the electrodes (395). It cannot be pretended, that any such electrolytic series of decompositions can go on by means of the minute and detached particles of hygrometric water contained in the paper material of Zamboni's disks: and admitting that moisture, thus existing, could, by its electrolytic decomposition, be adequate to sustain the electrical discharges for years (381), by what process is it transferred from surface to surface through the intervening paper? Evidently it cannot be conceived to pass by the series of decompositions and recompositions in rows of the atoms of an intervening liquid. Sturgeon avers, that the powers of De Luc's series is greater in proportion as the surfaces are kept brighter, so that chemical action, far from being necessary, is actually injurious to the energy of the apparatus.

Of Continuous Ignition.

442. I deem it expedient to distinguish, under the general designation of continuous ignition, those cases in which a body, to be ignited, is a good conductor (a wire or charcoal, for instance), forming that part of the galvanic circuit which lies between the electrodes (356). In this case a wire being uniform in diameter and shape, the length may be directly as the intensity. The larger the plates, the stouter the wire which can be rendered incandescent: the greater the number of the series, the longer. Within any reasonable limits, the sectional area for a given length may be as the area of the oxidizable surface of one pair; the length as the number of pairs in the series.

443. By the gigantic apparatus of Children, a platinum wire, five feet six inches in length, and more than one-tenth of an inch in diameter, was heated red-hot. By my deflagrator, several feet of wire of the same material may be raised to incandescence, and when consisting of iron, it may be burned by the atmospheric oxygen before fusion.

444. The platinum wire employed in igniting gaseous mixtures (C, 335), is liable to fusion, if care be not taken to break the circuit before the temperature reaches its maximum.

445. It is remarkable that if the wire, subjected to continuous ignition, be of uniform thickness, as is usually the

case with a wire in good preservation, the ignition begins about the middle, and extends gradually towards the electrodes.*

446. If a prism of well-burned charcoal be made to connect the poles of a powerful deflagrator, on completing the circuit, by bringing the plates and acid into contact, the charcoal will be instantaneously ignited throughout.

Of the Ignition of a Continuous Conductor by a Calorimotor or Deflagrator.

447. If the electrodes of a galvanic triad, of the construction to which the name calorimotor has been given, be united by a wire before the immersion of the plates; on immersing them, the wire will be more or less heated, according to the extent of the oxidizable metallic surface, and the size and length of the wire; excepting that the intensity produced by one pair lessens as its size is enlarged. Although on estimating the heat which it can produce, in wire of a certain magnitude, it may be found in *quantity* proportionable to the size, in order that this proportionable quantity may appear, the wire must have magnitude too

* As, when the wire is of a sufficient length, it takes some time for the whole to become incandescent, and as fusion cannot be effected in the central portion so long as the rest of the wire is below a white heat, the operator is enabled to avoid fusing the central portion, while raising it, nevertheless, to the highest temperature which platinum will bear. To effect the combustion of hydrogen with nitrous oxide, requires a heat so intense, that I always use a wire for that purpose of nearly two inches in length, and of about No. 26 of the wire gauge.

An argument in favour of the theory of Dufay has been founded upon the idea, that the heat taking place midway, corresponds with the meeting of two fluids at an intermediate space within the circuit equidistant from their respective sources. But it should be kept in mind, that agreeably to the theory of two fluids, the negative end of the pile has to receive as much vitreous as it yields up resinous, and the positive end has to receive as much resinous as it emits of vitreous electricity.

It follows, that the conditions necessary to electric activity, agreeably to that theory, consist in the simultaneous motion of two fluids in opposite directions. It cannot consist in their coming together at any particular part of the circuit more than in any other. It is true, that when the circuit is interrupted, an excess of vitreous electricity will be accumulated towards the positive end of the series, and an excess of the resinous towards the negative end; but, on completing the circuit, commensurate with the discharge of the vitreous accumulation into the anode will be a discharge of the resinous electricity in the opposite direction. In like manner, commensurate with the discharge of the resinous into the cathode will be an opposite discharge of the vitreous. The fluids are necessarily in motion throughout the circuit, to restore the equilibrium which the electro-chemical reaction is necessarily destroying.

The phenomenon under consideration, though irreconcilable either with the theory of one or that of two fluids, agrees with the idea of waves of polarization moving from the centre of the generating battery towards the extremities, thence passing through the metallic conductor to neutralize each other at an intermediate point in the wire. Possibly each wave, carrying with it caloric in a latent state, may yield it up when, by neutralization, the power to retain it ceases; and thus may arise the heat evolved at the place of meeting, so long as the current is sustained.

great to be consistent with intensity. Hence, a more *intense* heat may be produced in a fine wire by a triad of a square foot of oxidizable surface than by one of fifty. On this account it is necessary in a very large calorimotor to employ more than one triad in order to produce a white heat in a wire whether stout or fine* (331).

Of Deflagration.

448. Those experiments in which the contact or continuity of the conductor between the electrodes, after being established, is destroyed by its reaction with the current, or by the interference of the operator, fall under the head of deflagration.

449. Thus when suitable tapering pieces of charcoal, severally attached to the electrodes of an active and sufficiently powerful series, after being brought into contact, are separated, the resulting interval becomes occupied by an arc of flame of which the light and heat are the most intense that art can produce. It is not without pain, and the risk of permanent injury, that this flaming arch, or

* For more than twenty years, I have employed calorimotors for effecting the explosive combustion of gaseous mixtures, or for igniting a jet of hydrogen in oxygen in the Lavoisierian experiment for the synthesis of that liquid (834–5). In such experiments, that distinguished philosopher, and generally all the chemists of the old world, have used for the same object, the electric spark. This it is difficult to command in damp weather, and in the vicinity of the water usually employed in pneumato-chemical experiments.

In June, 1831, I was induced to make a series of experiments, in order to explode the charges of gunpowder in rock-blasting, and succeeded by one of my deflagrators in exploding twelve charges at the distance of one hundred and fifty feet. Of these experiments, I published an account in 1833, in the Franklin Journal, and recommended this process as peculiarly well suited for blowing up fortifications and blasting under water.

In England, about five years afterwards, efforts having been unsuccessfully made by other means of ignition, to remove the wrecks of vessels by the explosion of gunpowder previously introduced into their holds, galvanic ignition was resorted to pursuant to my suggestion. Nevertheless, upon the plea that my apparatus had not been employed to affect ignition "*under water*," resort was had to another, which was of course, previously to trial, amenable to the same objection. In fact, the deflagrator was peculiarly competent to effect ignition under water, far more so than the constant battery which was used. This arises from the completion of the circuit being affected by throwing the acid on the plates at the moment when the ignition is required. In this mode of operating, a transient power may be obtained far greater than can be had from an equal extent of surface in a constant battery.

Finally, however, Col. Paisley succeeded in blowing up the wreck of the Royal George, by means of galvanic ignition. Since then, a person by the name of Colt, has applied the process of galvanic ignition so successfully, as to blow up a vessel at the distance of several miles from the battery employed. In the employment of this process, it does not appear, that he made any due acknowledgment either as to Col. Paisley or myself. So entirely was the committee of congress with whom he conferred, in the dark, that in April last, both Prof. Joseph Henry, of Princeton, and myself, were applied to, by the Secretary of War of the United States, to give that information, which it was evidently Colt's duty to have given at the outset.

the bodies exposed to it, can be viewed by unprotected eyes.*

450. On comparing the light thus generated from nine hundred pairs of seven by three inches, with that of a candle, the ratio appeared to be as sixteen hundred to one. The shadow of the whiskers, or of a prominent lock of hair, partially intercepting the light, was cast upon a wall with extraordinary accuracy. The side of an adjacent house, on which the rays fell in the night, appeared as if illuminated by the sun.

451. When a rod of platinum, of a quarter of an inch in diameter, while attached to one pile, was made to touch charcoal attached to the other, the instantaneous fusion of the platinum at the point ensued. A knitting needle substituted for the rod of platinum was explosively deflagrated. In such cases the wire is destroyed in detail, the combustion being limited to the vicinity of the end. For this and other deflagrations where a metal is in question, it answers better to have one charcoal electrode, than to have both of metal. Two metallic electrodes are liable to be soldered or welded together. The incorporation thus arising, takes place even under water. A platinum wire brought into contact with an iron rod under water may be welded thereto. It is preferable to have one wire always stouter than the other. Of course tin-foil and other leaf metal are rapidly deflagrated by the same process as the knitting needle. A jet of mercury, so regulated as not to form a stream quite continuous, being made the medium of the discharge of a deflagrator, a splendid effulgence ensues, arising from the combined effects of the combustion of the metal and the galvanic light.

Deflagration with Liquids.

452. Let a concentrated aqueous solution of chloride of calcium be first brought fully into contact with a stout platinum wire, acting as the positive pole of a deflagrator

* On one occasion, after making some experiments with an extensive series, my eyes were so much affected, that all other flame appeared of a deep blood-red, and on the following day they were blood-shot, and so greatly inflamed, that it was deemed expedient to apply twenty leeches to each to procure relief.

On another occasion, similar consequences ensued to an assistant, who was not deterred from subjecting his eyes injudiciously to an ordeal like that which mine had undergone.

of about three hundred pairs, seven inches by three, in full operation. In the next place, let a platinum wire of about No. 30 of the wire gage, acting as the negative pole of the same series, be allowed barely to touch the solution, the most intense ignition will ensue, causing the platinum to be fused rapidly into globules, which will be found at the bottom of the solution. An analogous result ensues with other saline solutions, if capable of a similar degree of density. The fusion of the platinum, however, is much more readily effected with the chloride of calcium. This arises, I infer, from the extrication of the calcium, its union with the platinum momentarily, and subsequent rapid combustion by the oxygen of the water.

453. It is remarkable that this experiment could not be performed by a deflagrator of one hundred pairs of seven and a half by fourteen, although succeeding perfectly with three hundred pairs of seven by three, having less than two-thirds of the surface disposed in a series of an inferior number.

454. There is no mode by which a small portion of a substance can be subjected to heat in the absence of the oxidizing influence of the air, or with the co-operation of the deoxidizing affinity of hydrogen, so powerfully, as that of a large voltaic series acting in a receiver capable of exhaustion and replenishment with that gas or any other. Subjecting phosphuret of lime in this way to the intense ignition produced by two hundred pairs, each of nearly seven and a half by fourteen, I reduced the calcium very nearly to a state of purity, as a small portion acquired a metallic brilliancy under the burnisher, and decomposed water rapidly on being thrown into it.

455. Having, in like manner, exposed cyanide of calcium, the result was similar, but less exceptionable, as this compound does not possess the property of liberating hydrogen from water, so that the acquisition of the property indicated more certainly that the substance evolved was calcium. In either case lime was found in the water, in which the supposed calcium had been immersed.

Of the Electrolytic Power of Galvanism, or Galvanic Power of Chemical Decomposition.

456. The voltaic series was first discovered to have powers of decomposition, or electrolysis, by Nicholson and Carlyle. These ingenious investigators found, on subjecting water to copper wires acting as the electrodes of a voltaic pile, that while hydrogen was evolved at the negative electrode, the positive electrode was oxidized. But when wires of gold or platinum were used, both of the gaseous elements of water were evolved. In the following summer I was invited by my predecessor, Dr. Woodhouse, to see the experiment then going on in his laboratory, by means of a series constructed of disks of copper, zinc, and moistened cloth. This was considered as a great step in science at that time, when it was still denied that water could be decomposed, or that the hydrogen obtained by passing it in the state of steam over incandescent iron, was an element of that liquid. To the evolution of its gaseous elements by the voltaic pile, those who considered it as a compound, appealed with elation; and the proofs that it could be thus *electrolysed*, as we would now say, were finally such as to silence all who had been incredulous.*

* *Engraving and Description of an Apparatus for the Decomposition and Recomposition of Water, employed in the Laboratory of the Medical Department of the University of Pennsylvania.*

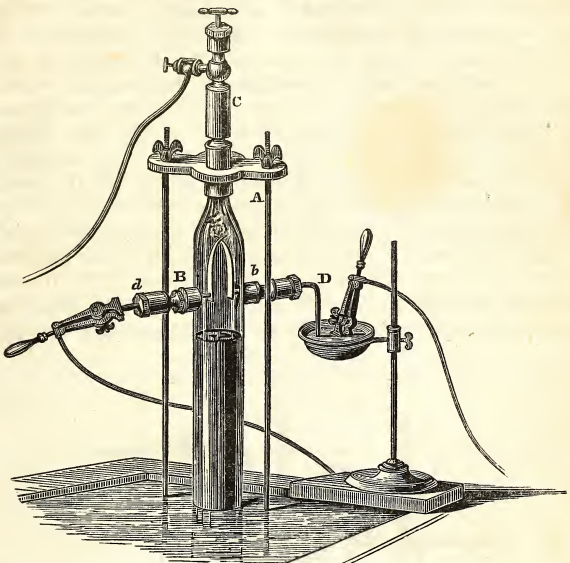
Having to illustrate the decomposition and recomposition of water to a class of between three and four hundred pupils, I have found it expedient to exhibit the process on an extensive scale. Hence, for many years, I have employed a glass tube of about two inches in bore, and about two feet in height, furnished with two tubulures, B, *b*, about three inches below the upper extremity, where the bore converges to an apex, having an aperture not larger than a goose quill. Upon this apex there is an iron cap, in which a female screw is wrought so as to allow a large iron valve cock, C, to be screwed into it.

Upon the tubulures iron caps are cemented, which are so wrought, as, with the aid of appropriate screws, to constitute stuffing boxes. Through each of these a platina rod, D, or *d*, is introduced, and fastened to plates of platina, to act as "*electrodes*," agreeably to the language of the celebrated Faraday.

The tube being supported over the mercurial cistern, by means of a communication with an air pump through the valve cock and flexible leaden pipe, the bore of the tube is exhausted of air, so as to cause the mercury to take its place. The mercury is so far displaced by a solution of borax, consisting of equal parts of water and a saturated solution of that salt, as to sink the surface of the column of metal in the tube about an inch or more below the "electrodes." The projecting end of one of the rods, D, *d*, to the other ends of which the "electrodes" are severally attached, is bent at right angles outside of the tube, so as to enter some mercury in an iron capsule, supported purposely at a proper height, and communicating with one end of my deflagrator of an hundred pairs of Cruickshank plates, described page 22. Of course the rod of the other electrode must have a communication with the other end

457. In 1807, Davy made the grand discovery of the composition of potash and soda, by means of two hundred pairs

Fig. 92.



of the deflagrator. Under these circumstances, if the circuit be completed by throwing the acid on the plates of the deflagrator, a most rapid evolution of hydrogen and oxygen will ensue in consequence of the decomposition of the water, so that within a few seconds, several cubic inches of gas will be collected.

The action being now suspended by throwing the acid off the plates, and the foam being allowed to subside, the resulting gaseous mixture may be ignited, and of course condensed, by completing the circuit again as at first, and at the same time causing the ends of the "electrodes" to come into contact with each other, and thus to produce a spark. This contact is effected by causing a very slight movement in the rod, bent at right angles, and entering the mercury in the iron capsule. Of course the process may be repeated as often as can be reasonably desired.

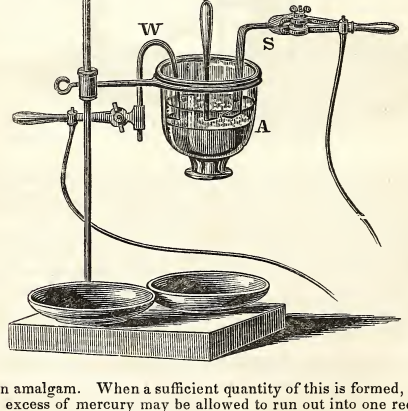
Generation of the Amalgam of Ammonium, upon a large scale, by "Electrolization."

An open necked bell, A, inverted and supported as in the figure, is furnished with a plug, P, by which the orifice in the neck may be closed or opened, more or less, as desirable. The lower part of the cavity of the bell is occupied by mercury, covered by a stratum of a concentrated solution of chloride of ammonium (sal ammoniac). An iron wire, W, so covered with gum elastic, as to pass through the solution of chloride without any conducting contact, establishes a communication between the mercury and the negative pair of the series. By means of a platina strap, S, a like communication is effected between the positive pole and the dissolved chloride. The circuit being completed, the mercury soon swells up, assuming the well known ap-

of four inch square plates. By Sweiger and Berzelius, analogous results were obtained by using mercury as the negative electrode. By the presence of this metal, the nascent metal of the earth subjected to the process, was to a certain degree protected from oxidation, which otherwise would have prevented it from being retained in a metallic state. Davy, by submitting the amalgams to distillation, obtained minute portions of barium and strontium, imperfectly deprived of mercury. In the distillation of the amalgam of calcium, he failed, as the tube broke before the process was complete. From my experiments, I infer, that with sixty grains of mercury, which was the quantity which he employed, he could not have obtained an available portion of the metal had the process succeeded.

458. By means of two deflagrators, each of one hundred pairs, seven and a half inches by fourteen (375), I was enabled, in 1839, to procure as much as 3600 grains of the amalgam of calcium. From this the mercury was dis-

Fig. 23.



pearance of an amalgam. When a sufficient quantity of this is formed, by loosening the plug, any excess of mercury may be allowed to run out into one receptacle, and afterwards the amalgam may be received in another; care being taken to close the aperture, by means of the plug, before the residual aqueous solution can follow. By these means about half a pint of the amalgam has been obtained. The diameter of the bell, which I have used, is about five inches.

It has been found advantageous to add liquid ammonia to the solution, in a sufficient quantity to prevent the evolution of free acid, which seems to destroy the amalgam when in contact with it beyond the influence of the circuit.

tilled, by means of a crucible included in a cast iron alembic, the cavity of the latter having been previously supplied with some pure caoutchoucine to expel oxygen. In this way I obtained sixty grains of calcium. In subsequent efforts I also succeeded in obtaining about the same quantities, respectively, of barium and strontium.*

On Secondary or Indirect Decomposition.

459. In the case of the decomposition of a liquid by wires, acting as electrodes, it was formerly inferred that the elements which appeared at the electrodes were liberated by a direct electrolytic influence, but Faraday has shown that the evolution of the element of one compound, another compound being present, may cause the decomposition of

* The cuts having unexpectedly been found to be missing, and not deeming it expedient to stop the press in order to replace them, I have to omit giving an engraving and description of the apparatus employed in the processes above mentioned (444, 458).

As no account of these metals, as procured by me, is given under Inorganic Chemistry, the statements made respecting them in the last edition of this Treatise are subjoined.

Properties of Calcium, Barium, and Strontium.

When the heat was sufficient to expel all the mercury, the metal was found adhering to the bottom of the crucible in a crust, which required an edge tool to detach it, though no incorporation of the iron with it appeared to have taken place. When in distilling calcium, a crucible of platina was employed, a portion of this metal was found to have united with some of the calcium, being detached therewith in the form of a bright metallic scale.

In consequence of their susceptibility of oxidation, and of union with the elements of naphtha, the metals obtained as abovementioned were devoid of metallic lustre until their surfaces were removed by a file or burnisher. Either was rapidly oxidized in water, or in any liquid containing it; and afterwards, with tests, gave the appropriate proofs of its presence. They all sank in sulphuric acid; were all brittle, and fixed, and for fusion, required at least a good red heat. After being kept in naphtha, their effervescence with water is, on the first immersion, much less active. Under such circumstances, they react at first more vivaciously with pure ether than with water, or even chlorohydric acid; because in these liquids a resinous covering, derived from the naphtha, is not soluble, while to the ether it yields readily.

By means of solid carbonic acid, obtained by Mitchell's modification of Thilorier's process, I froze an ounce measure of the amalgam of calcium, hoping to effect a partial mechanical separation of the mercury, by straining through leather, as in the case of other amalgams. The result, however, did not justify my hopes, as both metals were expelled through the pores of the leather simultaneously, the calcium forming forthwith a pulverulent oxide, intermingled with and discoloured by mercury in a state of extreme division.

By the same means I froze a mass of the amalgam of ammonium, as large as the palm of my hand, so as to be quite hard, tenacious, and brittle. The mass floated upon the mercury of my mercurial pneumatic cistern, and gradually liquefied, while its volatile ingredients escaped.

When the freezing of the amalgam was expedited by the addition of pure ether, the resulting solid effervesced in water, evolving ethereal fumes. This seems to show that a portion of this ether may be incorporated with ammonium and mercury, without depriving the aggregate thus formed of the characteristics of a metallic alloy.

the latter when the element first evolved has a predominant affinity for one of the constituents of the compound to which it is thus presented. Thus the deposition of a metal at the negative electrode from a solution of one of its salts, by exposure to the circuit, may be the consequence of its oxide being decomposed by the affinity of hydrogen in a nascent state as evolved from water. The nitrogen evolved at the anode from liquid ammonia, under like circumstances, is conceived to be liberated by the union of its hydrogen with the oxygen of water directly decomposed.

460. As in the electrolysis of salts of the alkalies and alkaline earths, when mercury is employed as the negative electrode, an amalgam is obtained of the metallic radical of the salt, I had formed the opinion that it is the metallic oxide which is the subject of direct decomposition, and that when hydrogen appears at the cathode it is the consequence of the decomposition of the water by the metal. It is known that as soon as either of these in its metallic state touches water, seizing the oxygen, it liberates the hydrogen of this liquid. Subsequently, I found that Matteucci, a distinguished Italian philosopher, had arrived at the same opinion as myself, on this subject, after performing a series of laborious experiments with a view to ascertain the truth.

461. This question must excite great interest from the fact, that it has an important bearing on the electrolytic investigations recently made by Daniell, which by Kane, Graham, and others, as well as the author of them, have been considered as justifying the salt radical theory. But in either way of viewing the subject, Faraday's suggestions that the elements, which are the ostensible products of the process, may be indirectly evolved, is fully sustained.*

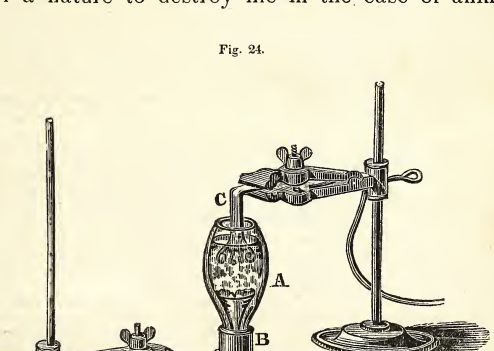
* Figure 24 represents an apparatus which may be conveniently employed for the electrolytic formation of amalgams with the metals of the alkalies or alkaline earths.

The lower end B of the receiver A is perforated so as to have an iron, or preferably a platinum wire, so luted therein, that one end may just enter the cavity of the receiver, while the other end is soldered to a metallic strap supporting the receiver, and held by a vice communicating through a wire rope with the positive end of a competent voltaic series. The lower part of the cavity of the receiver is occupied by some mercury, necessarily in contact with the end of the wire already described as entering that space. Upon the mercury a stratum of the aqueous solution containing the desired metal must be situated. By means of a strip of platina in contact with this solution at one end and at the other held by a vice in communication with the positive end of the voltaic series, the circuit is completed. Under

Results obtained by long enduring Galvano-Electric Currents of Low Intensity.

462. Becquerel and Were Fox, have drawn the attention of the scientific world to processes, in which galvanic currents long continued, of low intensity, have been successfully employed. It has been rendered probable by the investigations and observations of Were Fox, that galvanic circuits are among the most efficient causes of metallic depositions in mines, and by Becquerel, the processes of nature in the formation of crystals have been imitated. In this path, laborious experiments, of unprecedented endurance, have also been made by Crosse. It was during some efforts to produce by the voltaic current crystals, and other compounds, analogous to those found in nature, that this zealous electrician observed a species of louse, since called acarus galvanicus, to appear. It is certainly miraculous that these insects should come into existence under the influence of agents, which are never found to enter into the constitution of animals, and which are of a nature to destroy life in the case of animated

Fig. 24.



these circumstances, the series being in a sufficient degree of activity, the mercury acting as the negative electrode separates, and unites with any metallic cathion in any electrolyte held by the solution subjected to the process; meanwhile the anion of the electrolyte is evolved at the anode, or where the surface of the platina electrode is in contact with the liquid (358).

nature in general. The insect so much resembles a cheese mite, that it might be mistaken therefor on a hasty examination.

463. The experiments of Crosse have been repeated, with modifications, by Weekes of the London Electrical Society. This ardent investigator subjected to the galvanic current solutions of silicate of potash, in glass receivers over mercury, the greatest care being taken to guard against the access of any extraneous bodies. Under these circumstances, after an uninterrupted exposure during upwards of a year, insects are alleged to have made their appearance perfectly resembling those which seemed to come into existence during the experiments of Crosse. Mr. Weekes has since asserted that the acari appeared to have originated in a solution of ferroprussiate of potash. The origin of these insects is inexplicable, since it is utterly impossible that they can be *created* by the agents and process employed.*

* On this subject, in my Introductory, delivered in 1843, I expressed myself as follows:

A few years since, many of the more inconsiderate among the reading portion of society, were carried away by an account respecting certain experimental observations made by an enthusiastic electrician, to believe in the generation of certain insects through the influence of the voltaic current. It struck me at first, that, as nothing less than the miraculous interposition of the Deity could give rise to animal life, this narrative must be a jocular fiction, like the statement respecting certain observations of Herschel, in aid of which the light of the hydro-oxygen blow-pipe flame was employed to co-operate with the solar rays in illuminating bodies, on the lunar surface, at the distance of more than two hundred and thirty thousand miles!

It was, nevertheless, true, that an equivocal description had been given, in good earnest, tending to create the idea that animals had been generated by a voltaic current out of silicious earth, alkali and acid. It subsequently appeared, not that certain species of acari or lice had been created, but that they had been *stimulated to exhibit themselves* by the agents and apparatus employed. According to my apprehension, it had been quite as practicable to repeat the Mosaic miracle of bringing water from a rock, by the blow of a rod, without supernatural aid, as to create sentient organized beings by the materials and apparatus employed by the electrician. Far more reasonable were it to expect the formation of a watch by subjecting the ores of the metals requisite for its construction to the voltaic process.

Perhaps human genius has in no instance approached more nearly to the production of a machine having the attributes of an animal, than in the construction of the locomotive steam engine, of which the furnace may be considered as performing the office of a stomach, the cylinder and pipes that of the bowels, while the shaft, levers and wheels act as limbs; but still the will, the instinct, the power of self-reproduction, and the heaven-born sense of existence, are deficient.

In fact, human efforts have never attained the point of making a self-moving machine, or perpetual motion, however wrong-headed projectors may have deceived themselves and others with false expectations of success in that impracticable project. For, although there be in nature incessant movements, like those of the planets, or of waves, &c., and currents which, originating from calorific, or electrical changes, move or flow without intermission from age to age, such sources of motion are not to be created by man.

Important Inferences of Faraday, respecting Electrolysis.

464. Among many important services rendered by Faraday, is that of demonstrating that electro-chemical decomposition takes place in equivalent ratio, being always directly as the quantity of electricity which passes by the electrolytic separation and rearrangement of the ions (360). For the investigation of the phenomena dependent on this law, an instrument was devised by him, which, being interposed in the circuit, enabled him accurately to measure the gaseous products of the electrolytic decomposition of water. The result, thus obtained, was assumed as a standard by which to estimate the products of the decomposition of other electrolytes exposed to the same current simultaneously with water. To the instrument thus employed the name of volta electrometer, or by abbreviation voltameter, has been given. The construction of this instrument does not differ essentially from the apparatus above described for the decomposition of water (note to 450), excepting the absence in the latter of graduation, by which the volume of the gas generated is ascertainable on inspection.

465. By means of this apparatus it was ascertained, that when the fused chlorides of tin and lead were either severally or simultaneously subjected to the same active circuit, so that the products of their decomposition might be compared with those of water with water, the weight of the elements, evolved from this liquid, collected in the voltameter, and those of the chlorine and metals, liberated from the chlorides, were to each other as their equivalents, H 1, O 8, Cl 36, Pb 104, Sn 59, C (560).

466. By these results, and many others of an analogous character, it seems to have been fully established, that the quantity of any electrolyte which can be decomposed by a galvanic current is directly as the quantity of the electricity which passes through it: moreover, that the weights of different electrolytes discomposed by the same quantity, will be to each other, as the numbers by which their atoms are represented in the table of equivalents. The only motive for increasing the intensity by a numerical extension of the series employed, is that for the passage of the fluid by the electrolytic process, the requisite force must be as the reciprocal affinity of the ions of the electrolyte employed. Thus, as in the chloride of calcium, a stronger affinity is to be overcome than in decomposing the iodide of that metal, a greater number of pairs are required, but the quantity of the compounds in question decomposed, will be, *ceteris paribus*, as the *size* of the plates, without reference to the *number* of the series.

467. Not only did Faraday show that the weights of the ions evolved by the same galvanic current from different electrolytes, and consequently the weights of these, were to each other as their equivalent numbers, it was also shown by this skilful experimenter, that to produce the same quantity of electricity from different metals by galvanic reaction, the weights of the quantities corroded, must be to each other as the equivalent numbers of the metals.*

* It seems to me remarkable, that under these circumstances, no reference is made by Faraday to the analogous results, obtained by Pettit and Dulong, respecting specific heat. It is well known, that it was rendered highly probable, by these philosophers, that the quantity of heat given out by bodies was equally great for each atomic equivalent. The specific heat of every gas is the same, so that although the weight of equal volumes of gaseous hydrogen and oxygen are as one to sixteen, the quantity

An Interesting Summary of Faraday's Inferences.

The following summary of his inferences is given by Faraday.

468. "i. A single *ion*, i. e. one not in combination with another, will have no tendency to pass to either of the electrodes, and will be perfectly indifferent to the passing current, unless it be itself a compound of more elementary *ions*, and so subject to actual decomposition. Upon this fact is founded much of the proof adduced in favour of the new theory of electro-chemical decomposition, which I put forth in a former series of these Researches.

469. "ii. If one *ion* be combined in right proportions with another strongly opposed to it in its ordinary chemical relations, i. e. if an *anion* be combined with a *cation*, then both will travel, the one to the *anode*, the other to the *cathode*, of the decomposing body.

470. "iii. If, therefore, an *ion* pass towards one of the electrodes, another *ion* must also be passing simultaneously to the other electrode, although, from secondary action, it may not make its appearance.

471. "iv. A body decomposable directly by the electric current, i. e. an *electrolyte*, must consist of two *ions*, and must also render them up during the act of decomposition.

472. "v. There is but one *electrolyte* composed of the same two elementary *ions;* at least such appears to be the fact, dependent upon a law, that *only single electro-chemical equivalents of elementary ions can go to the electrodes, and not multiples.*

473. "vi. A body not decomposable when alone, as boracic acid, is not directly decomposable by the electric current when in combination. It may act as an *ion* going wholly to the *anode* or *cathode*, but does not yield up its elements, except occasionally by a secondary action. Perhaps it is superfluous for me to point out that this proposition has *no relation* to such cases as that of water, which, by the presence of other bodies, is rendered a better conductor of electricity, and *therefore* is more freely decomposed.

474. "vii. The nature of the substance of which the electrode is formed, provided it be a conductor, causes no difference in the electro-decomposition, either in kind or degree: but it seriously influences, by secondary action, the state in which the *ions* finally appear. Advantage may be taken of this principle in combining and collecting such *ions* as, if evolved in their free state, would be unmanageable.*

475. "viii. A substance which, being used as the electrode, can combine with the *ion* evolved against it, is also, I believe, an *ion*, and combines, in such cases, in the quantity represented by its *electro-chemical equivalent.* All the experiments I have made agree with this view; and it seems to me at present, to result as a necessary consequence. Whether, in the secondary actions that take place, where the *ion* acts, not upon the matter of the

of heat in the equal spaces which they occupy are equal; so that the specific heats of these gases are inversely as their densities or weights. The densities of hydrogen, oxygen, nitrogen, and chlorine, being respectively as 1, 8, 14, 36, the specific heats of equal weights of hydrogen, oxygen, nitrogen, and chlorine, are inversely as those numbers.

* It will often happen that the electrodes used may be of such a nature as, with the fluid in which they are immersed, to produce an electric current, either according with or opposing that of the voltaic arrangement used, and in this way, or by direct chemical action, may sadly disturb the results. Still, in the midst of all these confusing effects, the electric current, which actually passes in any direction through the body suffering decomposition, will produce its own definite electrolytic action.

electrode, but on that which is around it in the liquid, the same consequence follows, will require more extended investigation to determine.

476. "ix. Compound *ions* are not necessarily composed of electro-chemical equivalents of simple *ions*. For instance, sulphuric acid, boracic acid, phosphoric acid, are *ions*, but not *electrolytes*, i. e. not composed of electro-chemical equivalents of simple *ions*.

477. "x. Electro-chemical equivalents are always consistent; i. e. the same number which represents the equivalent of a substance A, when it is separating from a substance B, will also represent A when separating from a third substance C. Thus, 8 is the electro-chemical equivalent of oxygen, whether separating from hydrogen, or tin, or lead; and 103.5 is the electro-chemical equivalent of lead, whether separating from oxygen, or chlorine, or iodine.

478. "xi. Electro-chemical equivalents coincide, and are the same, with ordinary chemical equivalents."

479. It is much to the honour of Faraday that these opinions, which were mostly original, appear to be for the most part sanctioned by the scientific world. The greatest error is, as I conceive, in his language being of a nature to convey the idea of a loco-motion, which cannot take place agreeably to his own premises, and which I infer it was not his intention to treat as necessary to the electrolytic process. On this, I have already commented (397). Subjoined are some additional strictures (480, &c.).

On Sir H. Davy's Experiments on the Transfer of Acids through Alkalies, and of Alkalies through Acids by the Voltaic Currents.

480. When three vessels A, B, C, were associated by moistened strips of asbestos, so that the intermediate vessel A, held either an acid or an alkali, B, a saline solution, C, pure water, Sir H. Davy found that by taking them into a voltaic circuit, either an acid or alkali would reach the water of C. Hence it was inferred that, under the magic escorting influence of the current, an acid *ion*, as we now call it, might pass through an alkali, or an alkaline *ion* through an acid. Faraday treats this miraculous result as the natural consequence of the interposition of a body capable of combining with the ion during its journey. It seems, however, inconsistent with his adoption of the Grotherian hypothesis (389), respecting the mode in which ions are liberated by the current, that an ion should actually travel. Consistently with that view of the subject, in order that an acid ion should be liberated at the anode, and an alkaline ion at the cathode, there must be a row of compound electrolytic atoms, subsisting between the electrodes, in which the ions evolved are ingredients.

481. I trust that the following quotation from the work of his friend, Daniell, fully justifies my conception of the subject.

482. "We have now to consider how the impulse, which is derived from the zinc, is transmitted through the liquid to the platinum; and how we may account for the extraordinary fact, that the radical of a portion of the acid combines with the former, while the equivalent hydrogen, with which it was associated, is evolved upon the distant surface of the latter.

483. "No visible transfer of the disunited elements takes place, and if the vessel which contains the acid, be divided either by a diaphragm of bladder, a partition of porous earthenware, or other substance capable of imbibing the liquid, and the two plates be placed on its opposite sides, no impediment arises to this extraordinary separation.

484. "The force must be conceived to travel in this part of its circuit by

a species of convection, of which a mechanical illustration again may assist us in forming a just notion. When a number of ivory balls are freely suspended in a row so as just to touch one another, if an impulse be given to one of the extreme ones, by striking it with a hard substance, the force will be communicated from ball to ball without disturbing them, till it reaches the most distant, which will fly off under its full influence. Such analogies are but remote, and must not be strained too far; but thus we may conceive that the force of affinity receives an impulse in a certain direction, which enables the hydrogen of the first particle of aqueo-acid which undergoes decomposition, to combine momentarily with the radical of the next particle in succession; the hydrogen of this again with the radical of the next; and so on, till the last particle of hydrogen communicates the impulse to the platinum, and escapes in its own elastic form."

485. In order to render this resort to balls consistent with the phenomena which it is intended to enlighten, I conceive, that instead of supposing one row of balls, we must suppose two rows, one parallel to the other. At the same time, it may be expedient to imagine that one row, representing the anions, are white, while the other, representing the cathions, are black; and that they are arranged in pairs, each of which represents a compound atom of the electrolyte. It seems necessary, also, that there should be two impulses given, opposite in tendency, so that one operating upon each row, may cause the expulsion of an anion, at one end, from the white row, a cathion, at the other end, from the black row; the residue rearranging themselves within the same boundaries, so as still to exist in pairs, and to have no unpaired ball at either extremity. Meanwhile it is inevitable, that this loss of an anion and a cathion will be compensated by the access of another pair, of which, to make the analogy hold, there should be an abundance at hand. Moreover, the row, thus refitted, should, under the circulatory influence of the heat arising from the process, give place to another row, similarly constituted, and equally susceptible of electrolyzation. Thus it follows, from the illustration to which Daniell has resorted, when well carried out, that, consistently with his own explanation of the process of electrolyzation, there can be no travelling of an ion from one electrode to the other. It is alleged by him, that the force travels, per se, by a species of convection, without disturbing any other ball excepting that which may be at the extremity of the row (484). Hence, in conformity with the premises, it seems to me that an acid can only reach the cathode, through an alkaline solution, by the endosmosis of the salt and its subsequent decomposition.

Of the Electrotype or Galvanotype Process.

486. It has been represented, that during electrolysis, by a simultaneous exchange of partners throughout a row of atoms of water extending from one electrode to the other, an atom of oxygen may be liberated at the anode, and an atom of hydrogen at the cathode (358). Consistently, when a galvanic circuit comprises two electrolytes, separated by a porous diaphragm having a common anion, oxygen, for instance, but different cathions, as, for example, hydrogen and copper, this metal may on one side of the diaphragm perform the office which hydrogen performs on the other side. Hence, while at the anode oxygen will still be evolved, a deposition of copper will, at the cathode, be substituted for the evolution of hydrogen. Of course, if instead of a solution of the oxide of copper, any other metallic oxide be substituted, the deposition of the metallic radical will take place of the evolution of hydrogen, unless the radical be one of those which decom-

pose water on contact, at ordinary temperatures. If it be one of those, by the consequent decomposition of water, hydrogen will appear, as if water were the sole electrolyte. Analogous results will ensue, when any other simple electro-negative element is the common ingredient in electrolytes subjected to the galvanic current while separated by a membrane. Hence, in the electrotype process, which it is now the object to explain, only those metals can be employed, of which the deposition in the metallic state is practicable, in consequence of their not uniting with the oxygen of water.

487. It will be perceived, that there is a great analogy between the action of a simple battery for producing metallic depositions, and the constant battery of Professor Daniell. It is to the substitution of copper for hydrogen, as above mentioned, that the superiority of Daniell's battery is to be ascribed. By this change, cohesion between the cathion (360) and the surface of the conductor, acting as the copper plate in a galvanic triad (312, &c.), is prevented; and this conductor, incessantly renovated superficially, presents always a bright metallic surface to the liquid.

488. After a constant battery, of the construction thus described, has been in operation for some time, on removing the coating of metallic copper from the surface of the copper plate, it is found to constitute a sheet of the deposited metal of greater or less thickness, and which is a perfect fac simile of the surface on which it has been formed, excepting that depressions and elevations are represented in the new plate, in the opposite kind of relief. Although these results could not have escaped the observation of operators with the constant battery, no useful consequences flowed from the hint which they were of a nature to afford, until the year 1838, when, through the ingenuity of Mr. Spencer, of Liverpool, and of Mr. Jacoby, of St. Petersburg, the new and important arts of electrotype and electro-gilding were invented.

489. If a piece of coin* be made the negative surface of a simple gal-

Fig. 25.

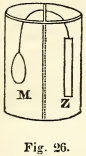
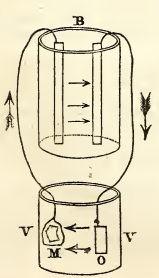


Fig. 26.



* Figure 25 exemplifies a constant battery, arranged so as to serve for the electrotype process. A plate of zinc, Z, is suspended in diluted sulphuric acid, on one side of the porous diaphragm, a medal on the other, being severally attached to the ends of a copper wire.

Figure 26 will convey an idea of another mode in some respects preferable. The mould M is connected by means of a wire with the zinc of a Daniell's constant battery, a coil of copper is connected by the same means with the copper plate. Thus arranged, the coil and mould, or medal, acting as electrodes, are plunged into a concentrated solution of sulphate of copper acidulated by sulphuric acid, contained in a vessel without any porous partition, the coil being made to enter the solution first. It has been mentioned, that the true zinc end of a galvanic battery is negative. Of course the metal communicating with the zinc becomes the negative pole or cathode of a galvanic triad, (358) while the copper coil becomes the positive electrode. Under these circumstances the copper coil is oxidized and dissolved by the acid, while an equivalent portion of this metal is deposited on the mould.

The roll of sheet copper should be introduced first into the solution and must not touch the mould. Great precautions as to cleanliness must be employed in this, as well as in the former method of manipulating. When an arrangement of this description is set in action, for each equivalent of zinc, dissolved in the battery, an equivalent of copper is dissolved from the coil of sheet copper, and is pre-

vanic battery, by attaching it to a piece of zinc by means of a short arc of copper wire, the zinc being acted upon by a saline or acid solution upon one side of a porous diaphragm, while the coin is plunged into a solution of sulphate of copper upon the other side, the coin will be speedily covered with a light rose-coloured film of reduced copper, which by continuing the action for some hours, will become proportionably thicker, and may then be separated from the coin, by the application of a moderate heat. The metallic plate thus obtained, as already mentioned, will display a perfect reverse impression of the coin, and by making the copy thus procured, the conducting surface of a similar arrangement, a perfect impression in relief of the original will result. The conducting wire, and all those portions of the coin upon which copper is not to be deposited, must be coated, or varnished, with a non-conducting substance. The surface to be copied must be perfectly free from uncleanliness, from grease especially. The zinc should be immersed in the acid a little before the coin is plunged into the metallic solution, and the surface of the last should then be freed from air-bubbles by means of a feather or glass rod. The rapidity with which the deposition is effected, is greater in proportion, as the temperature of the solution is higher. But there is a certain degree of speed which should not be exceeded, as the texture of the metallic deposition is more compact when the process is slow.

490. A more expeditious method of producing the copy of a medal in relief, consists in first making a copy, by stamping clean sheet lead upon it, or pressing it upon fusible metal, while sufficiently soft: or taking an impression on plaster, the surface of the cast thus obtained, being made to conduct by means of a film of plumbago. The impressions thus procured may be substituted for the medal in the process above described.

491. These last mentioned expedients are peculiarly appropriate in

cipitated upon the surface of the mould connected with the zinc plate. By interposing between the zinc and copper of the generating cell a number of deposition-cells, similar to that already described, the mould of one, being connected with the copper roll of the next, and so on in the same order, any number of medals or moulds may be copied at once, and at the expense of but a single equivalent of zinc.

The wires connected with the rolls of sheet copper should be varnished to prevent their being dissolved off the moulds, and the copper electrodes should be placed vertically and parallel to each other in the solution, and this last should be occasionally stirred with a glass rod to preserve an uniform degree of saturation throughout the mass of liquid.

Any conducting surface, negative to the zinc of the battery cell may be deposited upon in this apparatus. Hence, if surfaces of wax, wood, plaster, &c., be made to receive a thin coating of plumbago, by rubbing that material upon them with a brush, they may be made to receive a coating of metallic copper very nearly as uniform and as perfect as if they had been themselves of metal.

The accuracy with which the minutest elevations and depressions of a conducting surface may be copied, by means of the electrotype process, is so great, that the method has even been applied to the multiplication of Daguerreotype pictures; and the copies thus produced, are in every respect equal to the originals in perfection of finish and minuteness of execution. They possess, besides, the advantage of being indestructible by friction and slight mechanical injuries. For this beautiful application of the discovery of Spencer and Jacobi, we are indebted to Mr. Endicott, of New York.

The above described processes have not been confined to the production of electrotypes. They have been recently applied by M. Becquerel, in France, and by Jacobi, in Russia, to the separation of the precious metals from their ores: and agreeably to a statement made in some of the foreign papers, a mass of gold deposited in this manner, weighing half a pound, was presented a few months since to the King of Russia, by M. Jacobi.

copying engravings on copper, or wood, or in procuring stereotype plates from printing type set up so as to be ready for the press.

Of Electro-gilding and Electro-plating, &c.

492. But a more generally useful application of the principle is the electro-gilding and plating, now in almost universal use. If any polished article of steel, copper, or brass, be connected with the zinc of the battery, and placed opposite a fine wire of gold or platinum, connected with the copper of the same, and if the two electrodes thus formed be plunged into a very dilute solution of chloride of gold, or chloride of silver, to which an equivalent of cyanide of potassium in solution has been added, a deposit of gold or silver will be effected, and the article will receive a fine coherent film of gold or silver, with a polish equal to that of the surface on which the deposit is made. Platinum may also be worked in the same way, though the operation is very far from being uniformly successful, and further experiments are wanting to render the process less precarious.

493. The process of electro-gilding has been employed in England, by Prof. Wheatston, and in Germany, by Prof. Steinheil, for the protection of the reflecting surfaces of the specula of reflecting telescopes, and specula of good instruments may be multiplied indefinitely, as well as very cheaply, by taking electrotype casts of their surfaces, and then gilding the reflecting surfaces of the copper specula thus obtained.

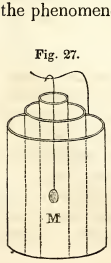
494. In depositing gold, silver and platina, by the electrotype process, it is necessary to employ currents of feeble intensity, and very weak metallic solutions, as the metals are very liable under the action of a very energetic current to be precipitated in a pulverulent form. By Mr. Davis, of Boston, the current of the magneto-electric machine was first employed for this purpose, and a patent has recently been obtained in England for the same process and manipulations.*

495. Besides the applications of the electrotype which we have noticed, many others have been contemplated or employed, of which a due regard to brevity renders it inexpedient to give the details in this treatise.

Of Metallo-Chromes.†

496. The name which forms the preceding head, has been given to certain beautiful colours, which may be produced upon a plate of highly polished steel by the electrolyzation of acetate of lead, while in contact with the steel surface. The following directions are given for the production of the phenomenon in question. Place the steel plate in a glass basin contain-

Fig. 27.



* Fig. 27 represents an apparatus suitable either for the process of electro-silvering, or that of electro-gilding. It consists of a jar of glass, or glazed porcelain, within which is situated a jar of porous porcelain containing the metallic solution (492). The space between the two jars is occupied by a cylinder of zinc, and sulphuric acid very much diluted. A wire proceeds from the zinc cylinder, as represented in the engraving, for the purpose of supporting the article which is to receive the metallic coating. It is recommended to dip the article, which is the object of the process, in nitric acid, just before placing it in the circuit.

† The etymology of this name from χρωμα, colour, in Greek, must be sufficiently obvious. As designating an iridescence produced by the peroxide of lead, it seems to me that a more appropriate appellation would be that of plumboxychromes.

ing a clear solution of the acetate of lead, and place over it a card, out of which some regular device has been cut. A small rim of wood should be placed over the card, and upon that a copper disk. On contact being made, from five to twenty degrees, in a circuit formed with two or three cells of a small constant battery, the steel plate being made negative, the copper disk positive, the deposit will be effected, and a series of exquisite colours will adorn the steel plate. These variegated tints are produced by the various tenuities of films of highly oxidized lead. Two sets of prismatic colours are produced, complimentary to each other, one by transmitted light, the other by that which is reflected from the steel. The colours are displayed, in the greatest perfection, by placing the plate before a window, and inclining over it a sheet of white paper, at an angle of forty-five degrees.

Of the Galvanic Powers and Effects of Animal Organs.

497. Under the preceding designation, it seems proper to treat of the galvanic apparatus and phenomena, which owe their existence to organic masses. It will be perceived by the student, who has given due attention to the preceding pages of this treatise, that this topic, has necessarily been in some degree anticipated. The references made to the convulsions produced in frogs, by an inherent electrical power, and to the shocks produced by electrical fishes, has already introduced organic galvanism to his notice.

498. Evidently of all the sources of the galvano-electric current, none are more interesting than the organs with which nature has furnished the torpedo, the gymnotus, and other electrical fishes.

499. *Of the Torpedo.*—Experimental evidence of the identity of the cause of the miraculous power of the torpedo, in giving shocks to other animals, seems first to have been satisfactorily obtained in the year 1792, through the exertions of Walsh, a sagacious electrician. In the following abstracts from a letter addressed to Dr. Franklin, this able observer gives an account of the facts which he had ascertained.

500. "It is with peculiar satisfaction, that I make to you my first communication, that the effect of the torpedo appears to be absolutely electrical. We have observed that the back and breast of the animal are in different electrical states, * * * we have been enabled to direct his shocks through a circuit of four persons, all feeling them; likewise through a considerable extent of wire, held by two insulated persons, one touching the back, and the other the breast of the fish. These experiments have been varied in many ways, and repeated times without number, and they all determined the choice of conductors to be the same in the torpedo as in the Leyden phial."

501. Respecting the torpedo, I will quote a few paragraphs from a report made to the Academy of Sciences at Paris.

502. "The sensation which the torpedo causes when it is touched, has long ago attracted the attention of physicists and physiologists, on account of its analogy with that produced by an electrical battery, but it is only a few years since that it has been decidedly proved that both were owing to the same cause. Although all the principal circumstances of this phenomenon had previously been carefully studied, yet no one had succeeded in demonstrating its electrical origin from the want of suitable apparatus.

503. "John Davy made known, in a paper published in 1832, a great number of important data, such as the action of the discharge upon the magnetic needle, and chemical compounds; but the direction of the electrical current produced on this occasion was not well known until after the experiments made at Venice, 1835, by two of your members, and from which it resulted that the superior part of the electrical organ gives positive electricity, and the inferior part negative electricity. Matteucci has confirmed, with the galvanometer and frogs prepared after the method of Galvani, the observations which we had made respecting this point, as well as others also relating to the torpedo, for which we are indebted to various philosophers; at the same time he has demonstrated some new facts, of which the following is a short account.

504. "He commences by showing that when the torpedo lances its discharge, no change of volume is observed in its body. When the animal is possessed of great liveliness the sensation is felt at whatever point of the body it may be touched, but when its vitality is considerably diminished, the discharge is no longer felt, except by touching the electrical organs at two different points.

505. "Matteucci establishes the general laws of the distribution of electricity in this manner:—1. All the points of the dorsal part of the organ are positive relatively to the points of the ventral part; a fact already known. 2. The points of the organ on the dorsal surface placed above the nerves which enter it are positive in respect to the other points of the same dorsal surface. 3. The points of the organ situated on the ventral surface corresponding to the points which are positive on the dorsal surface, are negative in respect to the other points of the ventral surface. 4. The intensity of the current varies with the extent of the platina plates which terminate the galvanometer, and with which the two surfaces of the organ are touched.

506. "When the torpedo is very excitable the current may be compared to that of a pile consisting of a great number of pairs charged with a good conducting active liquid; whilst, on the other hand, when its liveliness is weak, the electric current resembles that of a pile composed of a small number of elements.

507. "The spark which accompanies the discharge in the electrical fishes was remarked for the first time by Walsch in the *Gymnotis;* many vain efforts have been made since to reproduce it; MM. Matteucci and Linari have succeeded in obtaining it in every case from the torpedo; both these philosophers claim the priority of the observation.

508. "Matteucci has since succeeded in obtaining the spark by placing

the torpedo upon an isolated plate of metal, and placing another plate of metal above it, then fixing to each of them a gold leaf separated the one from the other by the distance of half a millimetre. By slightly moving the upper metallic plate the animal became irritated, and at the same moment the two leaves approached one another and the report of the spark was instantly heard.

509. "M. Matteucci having entirely separated from a great torpedo one of the electrical organs, without detaching the epidermis, one of the plates of the galvanometer was inserted in the organ near the outward edge, the other plate was put in communication with one of the four nerves: the needle deviated four degrees in the common direction of the discharge of the torpedo; on tying the nerves there was no longer any deviation. This result appears to us very remarkable.

510. "The above observations, which we have not been able to confirm from the want of torpedoes, go to prove, 1st, that the electricity which produces the discharge proceeds from the last lobe of the brain, and is transmitted by the nerves to the organ; 2, that the discharge ceasing under the influence of the electric current, when the nerves are tied, must, in order to be transmitted, find in the nerve a particular molecular disposition; a conclusion to which the electro-physiological phenomena of the frog equally lead, as one of us (M. Becquerel) has indicated in various places in his treatise on electricity.

511. "Since the ever memorable epoch when Galvani demonstrated that the contact of two different metals in communication with the muscles and nerves of a frog sufficed to make it contract, the experiments have been varied infinitely in the hope to discover in this phenomenon the cause which constitutes life in animated bodies. The most remarkable fact, for which we are also indebted to Galvani, is that which relates to the contractions produced by the simple contact of the muscles and nerves without the intermediary of metallic armatures. It is now nearly demonstrated that this action does not proceed from a chemical action, but from the inherent current of the frog, which has been indicated with so much sagacity by M. Nobili."

512. The opinion and facts with which these quotations tend to make the reader acquainted, seem to me to prove that if Volta was right in conceiving the powers of his pile as independent of vital action, still Galvani was justified in supposing that animal organization could give rise to analogous results.

513. *Of the Gymnotus Electricus.*—According to Humboldt, the gymnotus abounds in the small rivers which flow into the Orinoco. It employs its electrical powers as other animals do their horns, teeth, or fangs, to secure its prey, or repel aggression. Hence, horses or mules are attacked by them, when forced reluctantly to enter the streams in which they reside; and while, on the one hand, the quadrupeds suffer severely, from the shocks which they receive,

their assailants are so exhausted, as to be unable either to give further shocks, or to escape from seizure.

514. The gymnotus is sometimes five feet in length. One of the length of forty inches was lately conveyed to England, and put at the disposal of Faraday, who has given a most valuable account of the various phenomena noticed by himself, and other intelligent observers.

515. The shock was most powerful when the hands were made, the one to touch the animal near the head, the other near the tail, and was less severe in proportion as the distance between the hands was less. When the points of contact were in a line at right angles to the spine, little sensation could be produced.

516. The farther the hands were from the fish, while the line extending from one to the other was parallel to the spine, the less was the sensation experienced, and the diminution became greater in proportion, as the line joining the points of immersion deviated from parallelism with the spine.

517. Conductors of an ingenious construction, being applied to the anterior and posterior parts of the gymnotus, Faraday gives an account of the results in the following words:—

518. "A galvanometer was readily affected. It was not particularly delicate; for zinc and platina plates on the upper and lower surface of the tongue did not cause a permanent deflection of more than 25°; yet when the fish gave a powerful discharge the deflection was as much as 30°, and in one case even 40°. The deflection was constantly in a given direction, the electric current being always from the anterior parts of the animal through the galvanometer wire to the posterior parts. The former were therefore for the time externally positive, and the latter negative.

519. "*Making a magnet.* When a little helix containing twenty-two feet of silked wire wound on a quill was put into the circuit, and an annealed steel needle placed in the helix, the needle became a magnet, and the direction of its polarity in every case indicated a current from the anterior to the posterior parts of the gymnotus through the conductors used.

520. "*Chemical decomposition.* Polar decomposition of a solution of iodide of potassium was easily obtained. Three or four folds of paper moistened in the solution were placed between a platina plate and the end of a wire also of platina, these being respectively connected with the two saddle conductors. Whenever the wire was in conjunction with the conductor at the fore part of the gymnotus, iodine appeared at its extremity; but when connected with the other conductor none was evolved at the place on the paper where it before appeared. So that here again the direction of the current proved to be the same as that given by the former tests.

521. "By this test I compared the middle part of the fish with other portions before and behind it, and found that the conductor A, which being applied to the middle was negative to the conductor B applied to the anterior parts, was, on the contrary, positive to it when B was applied to places near the tail. So that within certain limits the condition of the fish exterternally at the time of the shock appears to be such, that any given part is negative to other parts anterior to it, and positive to such as are behind it.

522. "*Evolution of heat.* Using a Harris's thermo-electrometer belonging to Mr. Gassiot, we thought we were able in one case, namely, that when the deflection of the galvanometer was 40°, to observe a feeble elevation of temperature. I was not observing the instrument myself, and one of those who at first believed they saw the effect now doubts the result.*

523. "*Spark.* The electric spark was obtained thus. A good magneto-electric coil, with a core of soft iron wire, had one extremity made fast to the end of one of the saddle collectors, and the other fixed to a new steel file; another file was made fast to the end of the other collector. One person then rubbed the point of one of these files over the face of the other, whilst another person put the collectors over the fish, and endeavoured to excite it to action. By the friction of the files contact was made and broken very frequently; and the object was to catch the moment of the current through the wire and helix, and by breaking contact *during the current* to make the electricity sensible as a spark.

524. "The spark was obtained four times, and nearly all who were present saw it. That it was not due to the mere attrition of the two files was shown by its not occurring when the files were rubbed together, independently of the animal. Since then I have substituted for the lower file a revolving steel plate, cut file fashion on its face, and for the upper file wires of iron, copper and silver, with all of which the spark was obtained."†

525. It has been shown there are two ways in which we may increase voltaic power, one that of augmenting the quantity, the other, that of increasing the intensity. To the latter, the conducting power of water assigns a limit in the case of an animal created to live in that liquid. Of course, to secure to these electrical fishes the peculiar weapon with which they are endowed, there seems to be an enormous quantity of the requisite principle placed at their disposal.

526. The shock from the gymnotus, on which Faraday's observations were made, was, as he conceives, equivalent to that of a large Leyden battery charged to a low degree of intensity; or to a voltaic series of 100 pairs, of which the circuit should be completed for a moment.

527. He conceived it to convey a quantity of electri-

* "In more recent experiments of the same kind we could not obtain the effect."

† "At a later meeting, at which attempts were made to cause the attraction of gold leaves, the spark was obtained directly between fixed surfaces, the inductive coil being removed, and only short wires (by comparison) employed."

city equivalent to a high charge from a coated surface of 3500 square inches.

528. The gymnotus gives sometimes two, and at other times, even three successive shocks; as had been previously noticed in the case of the torpedo, by various distinguished observers.

529. At the moment when the fish wills the shock, of two parts of the body parallel to the spine, that which is nearer the head will be positive, the other negative.

530. The fish has four electric organs, which, it is conceived by Faraday, it may have the power to throw into action separately, or together, and so as, to a certain extent, to direct the shock at the moment of the discharge. But it is not inferred that the direction of the current can be controlled after it has entered the liquid or other surrounding bodies.

531. I saw the gymnotus with which these experiments were made in 1841, and received a shock from it. I was moreover gratified at seeing what I had not been led to expect, the deflagration of a thin metallic leaf by subjection to a circuit formed with the aid of the animal.

532. The gymnotus can stun or kill fish in various positions of its body, but in killing a small fish, thrown into the tub, was found to coil itself so as to make the fish occupy the situation of a diameter to the resulting coil. In an instant the fish was struck dead and motionless, and turning on its side, was soon bolted by its hungry assailant.

533. "Living (says Faraday) in the midst of such a good conductor as water, the first thoughts are thoughts of surprise that it can sensibly electrify any thing; but a little consideration soon makes one conscious of many points of great beauty, illustrating the wisdom of the whole arrangement. Thus the very conducting power which the water has; that which it gives to the moistened skin of the fish or animal to be struck; the extent of surface by which the fish and the water conducting the charge to it are in contact; all conduce to favour and increase the shock upon the doomed animal, and are in the most perfect contrast with the inefficient state of things which would exist if the gymnotus and the fish were surrounded by air; and at the same time that the power is one of low intensity, so that a dry skin wards it off, though a moist one conducts it; so is it one of great quantity, that though the surrounding water does conduct away much, enough to produce a full effect may take its course through the body of the fish that is to be caught for food, or the enemy that is to be conquered.

534. "Another remarkable result of the relation of the gymnotus and its prey to the medium around them is, that the larger the fish to be killed or

stunned, the greater will be the shock to which it is subject, though the gymnotus may exert only an equal power; for the large fish has passing through its body those currents of electricity, which, in the case of a smaller one, would have been conveyed harmless by the water at its sides.

535. "The gymnotus appears to be sensible when he has shocked an animal, being made conscious of it, probably, by the *mechanical impulse* he receives, caused by the spasms into which it is thrown. When I touched him with my hands, he gave me shock after shock; but when I touched him with glass rods, or the insulated conductors, he gave one or two shocks, felt by others having their hands in at a distance, but then ceased to exert the influence, as if made aware it had not the desired effect. Again, when he has been touched with the conductors several times, for experiments on the galvanometer or other apparatus, and appears to be languid or indifferent, and not willing to give shocks, yet being touched by the hands, they, by convulsive motion, have informed him that a sensitive thing was present, and he has quickly shown his power and his willingness to astonish the experimenter.

536. "It has been remarked by Geoffroy St. Hilaire, that the electric organs of the torpedo, gymnotus, and similar fishes, cannot be considered as essentially connected with those which are of high and direct importance to the life of the animal, but to belong rather to the common teguments; and it has also been found that such torpedoes as have been deprived of the use of their peculiar organs, have continued the functions of life quite as well as those in which they were allowed to remain. These, with other considerations, lead me to look at these parts with a hope that they may upon close investigation prove to be a species of natural apparatus, by means of which we may apply the principles of *action and reaction* in the investigation of the nature of the *nervous influence*."

537. I cannot perceive, with Faraday, that the facts above mentioned, as stated by him, are *all* consistent with the idea of the powers of the gymnotus, being due to a great quantity of statical electricity of low intensity.

538. The fact which appears to me inexplicable, upon this view of the subject is, that a shock should be received by a person having only one hand in the water containing the fish.

539. Agreeably to universal experience, no shock can be received by any person who is not within the electrical circuit through which the discharge is made; or of some other induced circuit in the vicinity. But within what circuit can a single hand be brought, unless the body and legs of the person to whom it belongs, the floor on which he stands, and the tub containing the gymnotus, be made to form a conducting communication between the organic electrodes of that animal. But if the electricity discharged through these electrodes be of an intensity too low for

them to discharge themselves through the water, a fortiori, it must be too low to make its way by means of the floor of which the conducting power must be vastly inferior to that of water.

540. I regret that it was not ascertained whether this result could not have been prevented by placing the tub upon glass legs, as dry as possible.

541. I doubt if a voltaic series of 100 large pairs, placed in water as the fish was, would cause shocks to a person on immersing only one hand.

542. A battery of 100 pairs, when out of water, will not, agreeably to my experience, give a shock to one hand. Of course, it could not do more when submerged in that liquid.

543. It is difficult to reconcile this fact with the idea, that the powers of the gymnotus are those of a large Leyden battery lowly charged, unless it be supposed that the animal is enabled to project the electric fluid in obedience to its will, as the porcupine has been supposed to shoot forth his quills.

544. The anatomical researches of Hunter, and other anatomists, have been considered as demonstrating, that the electrical organs of the torpedo, bear a very striking resemblance to a galvanic series in the columnar forms of the original pile of Volta. They have been alleged to consist of hexagonal columns, amounting in one instance, to one thousand one hundred and sixty-two, arranged like the cells of a honey comb, each column consisting of a pile of flat disks separated from each other by cellular tissue. The organ is abundantly furnished with nerves. Nevertheless, little satisfaction seems to have been afforded by the investigation of anatomists respecting the mechanism, by which nature has endowed this animal and other electrical fishes with their peculiar powers.

545. Both Matteucci and Schoenbien concur in considering, that neither dissections, observation, nor experimental inquiry, have thus far afforded any competent explanation of the apparatus by which the powers of the torpedo or gymnotus are imparted and made obedient to animal will. By the former it is alleged, "that it is impossible to find the least analogy between piles, secondary coils, batteries, and the electric organ of the torpedo:"

by the latter, after a careful repetition of the experiments of Faraday, with the same gymnotus, it is stated as the result of his mature consideration, "that the true cause of the phenomena is still completely obscure, and must neither be sought for in the physical or chemical constitution, nor in a fixed organization of certain parts of the animal; but that there exists, without our being able at present to determine how, an intimate connexion between the vital actions dependent on the will of the fish, and the physical phenomena which these vital actions produce."

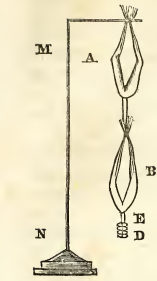
Of the Observations of Nobili, Matteucci, and Others.

546. It has been mentioned that Galvani considered that the convulsions produced in frogs by contact with metals, or the proximity of the discharges from the conductor of an electrical machine, as more or less dependent on a diversity of electrical excitement in the different animal organs.

547. That Volta having subsequently discovered his pile to be capable of producing effects altogether independent of the animal, similar in their character and vastly more powerful than those noticed by Galvani; this eminent philosopher was led into an error, which was generally adopted, of supposing that the organs of a frog, when convulsed by an electric discharge, are in all cases the medium, not the source of the current. Yet the recent observations of Nobili and Matteucci, have shown that although the impressions of Galvani may not have been warranted by any of his own experiments, they are fully justified by those which have been recently made.

548. From the experiments of Matteucci, it appears, that in frogs there is a current, peculiar to them, proceeding from the feet towards the head. This can be made sensible either by the deviation caused in the needle of a very delicate Sweiger's galvanometer of 2500 circumvolutions, or by the contractions produced in the leg of another frog, of which the denuded spinal nerve is made the medium of discharge. I shall call a frog's limb and nerve thus prepared, a galvanoscopic frog limb. To produce the current in question, only the leg of the animal is necessary; although, in several experiments, the leg, thigh, denuded nerve, and a portion of the spine, are mentioned as being employed. The author in one of his summaries, uses the following language: "*Each member of a frog, comprising the leg, thigh, spinal nerve, and a small portion of the spine, constitutes a complete electromotor.*" Yet it fully appears from his subsequent narrative, that the thigh, nerve, and spine, contribute nothing to the electromotive energy. The nerve, from its low conducting power, rather diminishes than increases the intensity of the discharge. It follows, that the statement, above made, should have been reserved for the leg of the frog; which, agreeably to the author's observations, is really an electromotor as much as any galvanic triad (312). It does not appear to be determined, what portions of the leg perform respectively the parts of copper and zinc: the sanguineous liquid, retained in the pores of the flesh, seems to act as the electrolyte.

Fig. 28.



549. Nobili had found, that by disposing a number of frogs in such order as to resemble a voltaic series, an increase of power in the resulting electrical current would ensue. To construct such a series, it is sufficient that the frogs, duly prepared, be supported by one or more non-conductors, so that their dissimilar extremities may be in contact, or communicate through weak brine, forming thus a species of couronne des tasses. The adjoining figure illustrates one convenient mode among others, by which the frog limbs may be connected, so as to be in voltaic order. Of course the series might consist of several similarly associated. M N is a glass rod, by which the frog's limbs, A, and those at B, are supported and insulated. According to Sturgeon, when the spine, D, of B, is, by means of another glass rod, brought into contact with the feet of A, convulsions are produced. Moreover, it will be seen, that agreeably to the experiments of Nobili, and those of Matteucci, when a conducting communication is made between the extremities of such an organic series, through the coil of a galvanometer of 2500 circumvolutions, deviations are produced, which are, as far as tried, greater in proportion to the number of the series.

550. At first the frogs thus employed were prepared as above described, so as to consist of the legs, thighs, and a bit of spine, but Matteucci discovered that, as naturally associated, one limb operated in some degree as a discharger to the other, so that on the removal of one, the other became more efficient. It has been mentioned that the thigh and nerve added nothing to the electromotive power. Accordingly it was found that a battery might be made of legs only, the feet belonging to one leg touching the denuded muscular extremity of another, so that the dissimilar parts of the whole number were in contact in voltaic order (362).

551. Of the voltaic series thus formed, the effects upon the needle of the galvanometer increased within certain limits with the number, so that when one element could produce a deviation of only four or five degrees, the series would produce fifteen to twenty degrees.* These deviations were of a nature to show that the current sets invariably from the feet towards the rest of the limb. The current, thus described, is designated by Matteucci as the current proper to the frog. He has not been enabled to detect any thing analogous to this current in any other animals of a neighbouring grade, such as lizards, tortoises, or eels.

552. Nevertheless, agreeably to the same authority, currents may be shown to take place from the internal to the external portions of the muscles of both warm and cold blooded animals, by which, deviations in the galvanometrical needle and contractions in a galvanoscopic frog's leg may be produced, as striking as those resulting from the current proper to frogs.

553. Sections of thighs of frogs, of the bodies of eels, or of the thighs of rabbits or pigeons, being arranged in a series of eight or ten on a varnished plank, so that the internal surface of one should touch the external surface

* The deviations of the needle of a galvanometer are estimated by a semi-circle, graduated to ninety degrees on each side of the point at which it rests when undisturbed.

of the other in voltaic order (362), the batteries thus formed of eels, consisting of two elements, caused deviations of two degrees; when the series was extended to five, a deviation of twenty-eight degrees was obtained. A battery of sections of tench, of two elements, produced five or six degrees, while four elements produced twelve degrees. Similar results were obtained with batteries made either with hearts of pigeons, or with the muscles of beef, mutton, or poultry.

554. The following inferences, by the ingenious and indefatigable author, are made from his investigations.

555. That in all cases where a conducting communication is established between the interior portion of the muscle of a recently killed animal, and the external, the skin being removed, a current is established from the inner parts to the outer.

556. That this current varies as to intensity according to the animal whose muscles are employed.

557. That by disposing duly made sections of muscles, such as above described, in a series, voltaically, the intensity of the current is in proportion to the number of the sections so associated.

558. The author adverts to a fact which he had himself ascertained, that when water and blood communicate through a liquid conductor, a current is induced from the latter to the former. Foreseeing that this may be represented as accounting for the current from the inside to the outside of animal muscle, he points out that a current, resulting from sanguineous matter in the muscle and the water used as a conductor, would be the opposite in its effect on the needle to that observed, which is only to be reconciled with the direction being from the water towards the sanguineous matter. But a conclusive answer to the objection thus founded, is, that if the effect on the galvanometer were due to the electromotive influence of blood and water, arranging the sections, so as to form a voltaic series, could not have augmented the intensity as it was actually ascertained to do.

559. Further, it is alleged that the current detected in being generated between water and blood, endures without diminution of intensity, while that which takes place in the muscles of recently killed animals is transient, and ceases sooner in proportion as the animal is of a higher order.

560. Contractions were produced in the leg of a galvanoscopic frog, when the nerve was made to complete the poles of a thigh series, by strips of moistened paper. Even when the paper was so extended in length, as that the galvanometrical needle was not affected by placing the terminating platina blades in contact with the paper at different points, on making like communications between the paper and frog, contractions ensued. The longer the strip of paper employed for a part of the circuit, the greater the number of the sections requisite to produce the contractions.

Of Galvano-Electrical Currents in Living Animals.

561. In the next place, we are informed in what manner to obtain indications of galvano-electrical currents in living animals. The process is simply to touch the bottom of a wound with one of the galvanometrical blades, while the other is made to touch the surface of the wounded muscle. Under these circumstances, deviations of twenty, thirty, or forty degrees may ensue, directed from the former place of contact to that last mentioned. The indications cease after two or three immersions in the same wound, and not unfrequently they are followed by a contrary deviation.

562. An experiment is described, in which several live frogs were subjected to a process, which may be literally considered as excruciating, by nailing their feet against a varnished plank, removing their legs, skinning their thighs, and in cutting in half each alternate thigh; then the uncut thigh of the first, and the raw surface of the remaining half of the next thigh, were brought into contact in voltaic succession. By these, a series of four elements gave a current of twelve degrees, always from the interior to the surface.

563. The galvanometrical deviations caused by a current obtained from a live sheep, or rabbit, by the means above described (560), was more than six times greater than those obtained from a frog in like manner.

564. The potency of muscular batteries, in which the size of each element in one, was uniformly double or triple that of those in the other, was found nearly the same; since, when they were so arranged as that the one counteracted the other, there was scarcely any current produced by the excess of power in the larger element. When, of two batteries of frog thighs, of the same size and number, the nerves were removed only from one, no diversity of power was found to ensue: so that the muscular current depends neither as to quantity, nor as to intensity, on the integrity of the nervous system of motion and sensorial power. Two batteries of ten elements each, being constructed, the one of the thighs of frogs, of which the spinal marrow had been destroyed by a hot iron, and their lower limbs thus paralyzed, the other differing only in being made from animals of the same kind, in which the spine had sustained no injury, it was found that where the two batteries were made to act in opposition in the same circuit completed by the galvanometor, the deviations of the needle in the direction of the former, was from sixteen to eighteen degrees. In fact, this battery gave separately, from fifty to fifty-five, while the other gave only from forty to forty-five degrees.

565. This is considered as confirming the inference already made, that the integrity of the motive and sensorial nervous system, has no bearing on the intensity or the direction of galvano-muscular currents. Whether or not, the frogs from which batteries were constructed, had been rendered drowsy by opium, nux vomica, or other narcotic poisons, made no difference in the currents which they gave; excepting in one instance, in which it seemed as if a feeble dose augmented the power of the current. Moreover, it is not to be inferred, that the capacity to produce a current, is not enfeebled or destroyed, when narcotics have been used to an extent to produce death. Frogs, thus poisoned, are as unsuitable for a battery, as those which have been dead for a much longer time, after being killed and prepared in the usual manner. In operating with the muscles of a pigeon, which had been more or less poisoned, similar results were attained. Contrasting the galvano-electric power of equal series of the muscles of frogs or pigeons killed by immersion in carbonic acid, cyanhydric acid, or arsenuretted hydrogen, and of such as were killed as usual, no superiority was found in any case, excepting that a little superiority appeared in the muscles of those which had been poisoned. Yet, in the case of muscles from frogs, or pigeons, killed by sulphuretted hydrogen, a great loss of power was discovered, as contrasted with the muscles of animals prepared in the ordinary way; since, when by a similar series of the latter, scarcely any deviation could be obtained, by the former fifteen degrees were effected.

The following is the author's summary of his inferences.

566. 1st. The intensity of the galvano-muscular current, as measured

by deviations of the galvanometrical needle, varies in cold blooded animals proportionally to the temperature of the medium in which they have lived for some time previously to the experiments.

567. The durability of the current, is less in proportion, as the animal is more elevated in the scale of beings.

568. The intensity of the current varies as the animal has been better or worse fed, and is invigorated by inflammation, or sanguineous congestion, resulting from a wound.

569. It is independent of the integrity of the nervous system, as respects the sensorial and motive power.

570. Narcotic poisons have scarcely any influence on this current as respects intensity, and as to its direction they have none.

571. Among gaseous poisons, sulphuretted hydrogen, is to a striking extent, productive of an enfeebling influence, while cyanhydric acid, or arseniuretted hydrogen, if productive of any change, strengthen it a very little.

572. The direction and the strength of the galvano-muscular currents are altogether independent of any assistance from the nerves, which act only as imperfect conductors, representing and transmitting the electric excitement of the muscle with which they are associated.

573. Messrs. Pacinotti and Puccinotti, of Pisa, in a great many experiments, in which one of the blades of a galvanometer was plunged into the leg, the other into the brain, obtained deviations of the needle, which were at the same time sufficiently striking, and of a nature to demonstrate the existence of a current flowing from the brain towards the muscular parts of the animal fabric.

574. Alluding to these results, Matteucci adverts to the difficulty of avoiding erroneous results. He suggests that the action of the blood which flows copiously from the wound in the brain as usually made, is sufficient by its reaction with the terminating blades of the galvanometer, to produce deviations, especially as, in order not to diminish the vitality of the animal, it had been preferred to perforate the head the last. Merely the friction resulting from moving the blades is sufficient to increase the deviations. But having himself taken various precautions, the deviation on first immersion, was always such as to comport with a current in the direction from the brain towards the feet, as observed by the electricians above named. From Matteucci's statement, that deviation varied from eight to ten degrees, and as the current did not persist in its direction after the first plunge, was very much enfeebled after the third immersion, and was very often reversed, it does not seem that much reliance is to be placed on the existence and direction of the current in question.

575. Assuming, however, that there is a current from the brain towards the lower parts of the body or limbs, our author conceives, that it is a consequence of the nervous system acting as a conductor to the muscular masses into which the nerves ramify. Yet, he admits, that this idea is not altogether compatible with the fact of the production of a current equally either by a contact with the interior of any of the muscles, or with any of the muscular surface; and, further investigation is requisite for the elucidation of this subject.

576. The author concludes with this observation. Perhaps the nervous system may exercise on the galvano-animal current an indirect influence, arising from its participation in the process of muscular nutrition, which it is not, however, possible to prove by direct experiments.

EXHIBITION OF VOLTAIC SERIES OF VARIOUS CONSTRUCTIONS.

577. Voltaic Pile, as originally constructed, exemplified —also the Couronne des Tasses.

578. Apparatus, employed by Sir Humphrey Davy, exemplified by two porcelain troughs, in each of which are suspended ten pairs, consisting severally of a zinc and a copper plate.

579. Apparatus exhibited, in which the cells are made by partitions of glass, and the galvanic pairs, instead of being attached to beams in order to be lifted out of the acid, are kept permanently in their cells; the acid being removed by a partial revolution of the trough upon pivots, when the action is to be suspended.

580. Construction of Cruikshank pairs and trough illustrated.

581. Galvanic deflagrators exhibited of various dimensions and numerical extension, combining the advantages of the Cruikshank trough with those of the deflagrator.

582. Effect of the circuit upon the animal frame.

583. Iodine evolved and made evident by starch.

584. Water decomposed, and recomposed.

585. Various apparatus for different amalgams produced.

586. Deflagration, fusion, and volatilization of charcoal, metals, anthracite, and plumbago, exhibited. Likewise of various metallic wires, of tin-foil, tinsel, and mercury. Fusion and incorporation of iron and platina, under water. Hydrate of potash deflagrated upon charcoal, and upon a piece of silver coin.

587. Fusion of platina, on contact with chloride of calcium and other solutions in the voltaic circuit.

588. De Luc's columnar apparatus exhibited and explained.

Exhibition of

Grove's gas battery.

Daniell's original constant battery.

Improved constant battery.

Grove's sustaining battery.

Apparatus and processes for electro-typing, also for electro-gilding and silvering, &c., and metallo chromes.

Of a Process for Rock-blasting.

589. I have already adverted to the efficacious and perfectly safe process, for rock-blasting and blowing up wrecks of vessels, fortifications, &c., with which I contrived, in 1831, to ignite twelve charges of gunpowder at the distance of one hundred and fifty feet (447). Hoping that it will serve the cause of humanity to make this process better known, I subjoin the original account of it as published in the Journal of the Franklin Institute in 1833, Vol. XX. page 221.

Description of a Process and an Apparatus for Blasting Rocks, by means of Galvanic Ignition. Communicated by Robert Hare, M.D., Professor of Chemistry in the University of Pennsylvania.

590. I have observed various accounts in the newspapers of workmen killed, or dreadfully lacerated, by the blasting of rocks.

591. I have ascertained that by a new application of galvanism, rocks may be riven with less danger than that which attends the firing of a pistol. I was induced to attempt this improvement in consequence of an application by a patentee (Mr. Moses Shaw,) for assistance in perfecting his patented mode of blasting rocks, by an electrical discharge from a Leyden jar.

592. In a letter dated June 1st, 1831, he says, "I have been engaged in blasting rocks by means of a fulminating powder, introduced into several cavities, and ignited in all of them simultaneously, by a spark from an electrical machine, by which means masses of a much larger size, and of a much more suitable shape, for any object in view, may be procured, than by the old plan. I have, however, to lament my inability to succeed in this method of blasting, during a great part of the year, when, in consequence of the unfavourable state of the weather, the ignition cannot be effected by electricity in any mode which I have devised, or which has been suggested by others, although I have consulted all the best informed professors to whom I have had access."

593. It occurred to me, as soon as this statement was made by Mr. Shaw, that the ignition of gunpowder, for the purposes he had in view, might be effected by a galvanic discharge from a deflagrator, or calorimotor, in a mode which I have long used in my eudiometrical experiments to ignite explosive gaseous mixtures. This process is free from the uncertainty, which is always more or less attendant upon the employment of mechanical electricity, for similar purposes.

594. The expectation thus arising, has since been fully verified. I have ignited as many as twelve charges of gunpowder at the distance of one hundred and thirty feet, from the galvanic machine employed. This distance is much greater than is necessary to the safety of the operator, as the deflagrator may be shielded so as not to be injured by the explosion, and by means of levers and pulleys it may be made to act at any distance which may be preferred. There is no limit to the number of charges which may be thus ignited, excepting those assigned, by economy, to the size of the apparatus employed.

595. These remarks have reference to the principal and highly important object of Mr. Shaw's project, which is to ignite at once a great number of charges, in as many perforations so drilled in a rock, as to coöperate simultaneously in the same plane. By these means it is conceived that the stone may be separated into large prismatic, or tabular masses, instead of being reduced to irregular fragments of an inferior size. The object to which I propose now to call attention more particularly, is a modifica-

tion of the common process of blasting by one charge, which renders that process perfectly safe.

596. This part of the subject I shall introduce by premising, that almost all the accidents which have taken place in blasting rocks, have occurred in one of the three following modes :—

1st. The explosion has taken place prematurely, before the operator has had time to retire.

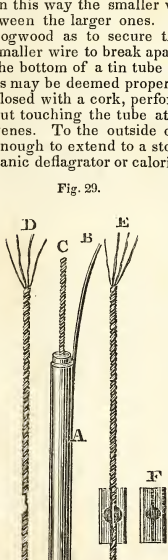
2d. A premature explosion has ensued from a spark produced by the collision arising from ramming into the perforation, containing the powder, the brickdust, or sand, or other matter, employed to close it.

3d. The fire not reaching the charge after the expiration of a period unusually long, and the operator returning to ascertain the cause of the supposed failure, an explosion ensues when he is so near as to suffer by it, as in the instance near Norristown, published some years ago.

The means of communicating ignition, to which I have resorted, are as follows :—

597 Three iron wires, of which one is of the smallest size used for wire gauze, the others of the size (No. 24,) used by bottlers, are firmly twisted together. This is best accomplished by attaching them to the centre of the mandril of a lathe, which is made to revolve while the other ends of the wires are held by a vice, so as to keep them in a proper state of tension. After being thus twisted, a small portion is untwisted, so as to get at and divide the larger wires by means of a pair of nippers. In this way the smaller wire is rendered the sole mean of metallic connexion between the larger ones. These are tied in a saw kerf, so made in a small piece of dogwood as to secure them from working, which, if permitted, would cause the smaller wire to break apart. At one end, the twist formed of the wires is soldered to the bottom of a tin tube of a size to fill the perforation in the rock to such a height as may be deemed proper. This tube being supplied with gunpowder, the orifice is closed with a cork, perforated so that the twisted wire may pass out through it without touching the tube at any point above that where the finer portion alone intervenes. To the outside of the tube, a copper wire, about No. 16, is soldered, long enough to extend to a stout copper wire proceeding from one of the poles of a galvanic deflagrator or calorimotor. The wire passing through the cork from the inside of the tube, is in like manner made to communicate with the other pole. The connexions between the wires and the poles, should be made by means of soft solder, previously to which we must imagine that the tube has been introduced into a perforation made for its reception in a rock to be blasted. The tin tube may be secured within the rock by the usual method of ramming in brickdust or sand, by means of a plug, having holes for the protection of the wires of communication already described.*

Fig. 29.



598. The apparatus being thus prepared, by a galvanic discharge, produced by the movement of a lever through the quarter part of a circle, the finer wire is ignited, in the place where it intervenes solely in the circuit, so as to set fire to the surrounding gunpowder.

599. As the enclosure of the gunpowder in the tube, must render it impossible that it should be affected by a spark elicited by ramming, as no means of ignition can have access to the charge besides the galvanic discharge; and as this can only occur by design, without an intention to commit murder or suicide, or by unpardonable neglect, it is inconceivable that an explosion can take place in this method of blasting, when any person is so situated as to suffer by it.

600. It must be obvious that in all cases of blasting under water, the plan of a tin tube, and ignition by a galvanic circuit, must be very eligible.

601. At A is represented a cylinder or tube of tinned iron, replete with gunpowder. At C, the twisted wires are represented as they protrude from the cylinder through a cork, by which the latter is closed at the upper end.

* It has occurred to me that plaster of Paris might be used advantageously, as it would require no ramming, and might set with sufficient firmness.

The other ends of the wires are soldered to the metallic disk which forms the bottom of the cylinder. D represents the twisted wires as they appear when all the larger ones are cut, the smaller wire still uniting them. F represents the piece of dogwood, duly prepared; and E the wires as when supported by the wood. The reader has only to imagine the hole in the wood to be supplied with the fulminating composition, and covered by a fillet of paper or cloth, glued or pasted around the wood, in order to complete his conception of the wires as finally accoutred and situated within the cylinder A.

602. Besides affording support to the larger wires, and thus protecting the smaller wire uniting them from fracture, the piece of dogwood which has been described, by means of the small hole represented in it, serves to hold, and to preserve in contact with the little wire, some fulminating powder. This not only facilitates the incipient ignition of the contents of the cylinder, but must make it extend more rapidly throughout the mass, and must, of course, cause it to be more powerful. Metallic arsenic, and chlorate of potash finely powdered and mingled, make an excellent explosive powder for this purpose; being more ready to explode from heat, and less so from other causes, than fulminating silver or mercury. Sulphur may be used in lieu of arsenic. Yet the use of these is not necessary, as the gunpowder will take fire directly from the wire, at least as effectually as in the usual mode. The mixture of gum phosphorus, sulphur and chlorate of potash used for matches, would answer, no doubt, in lieu of the preparation mentioned.

ELECTRO-MAGNETISM.

720. The science of Electro-magnetism may be said to consist of a knowledge of a series of facts ascertained respecting the influence of active electric circuits with each other, or with bodies which may have been magnetized, or which are susceptible of being rendered magnetic. To describe and illustrate experimentally, some of the most striking among the facts, to which allusion is thus made; giving also such theoretic elucidation as the present state of science will afford, is all that the limits prescribed to this treatise will permit.

721. The science of Electro-magnetism may be considered as comprising the following branches, each producing, as its appropriate fruit, phenomena, which are not only highly wonderful and interesting, but likewise of great practical importance.

SYNOPSIS.

Reciprocal reaction of Magnets.

Reaction between Magnets and Electrical Currents.

Attraction and Repulsion between Electrical Currents and the Movements thence arising.

Induction of Currents by Electrical Currents, or Electro-dynamic Induction.

Induction of Magnetism by Electric Currents, or Electro-magnetic Induction.

Induction of Electric Currents by Magnetism, or Magneto-electric Induction.

722. It had long been observed, that there were striking analogies, as well as discordancies, between the characteristics of electricity and magnetism. The similar poles of magnets, freely suspended,* were observed to recede from each other, and dissimilar poles to approach each

* Allusion is here made to what is called usually a magnetic needle, as represented in figure (35).

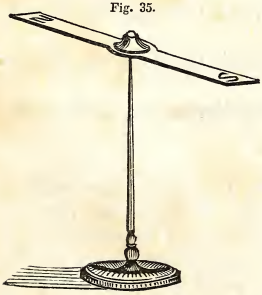
other, in a mode quite analogous to the separation or approximation, under like circumstances, of substances similarly or dissimilarly electrified.

723. It had also been observed, that iron, in the vicinity of lightning rods, or otherwise indirectly affected by lightning, had in some instances been rendered magnetic.

724. So far then, the existence of an analogy, or of an association, between electrical and magnetic phenomena was demonstrable; but, the magnetic repulsions and attractions took place under circumstances extremely unfavourable to the existence of the opposite electricities. The magnetic needle being a perfect conductor, there could of course be no permanent existence of opposite ordinary electrical excitement at the extremities. Moreover, neither pole of a magnet was more susceptible of being attracted by electrified bodies, than any other metallic wire, similarly suspended; nor did either of the electricities affect one pole more than the other. The poles of the voltaic apparatus were found to be perfectly indifferent to those of a magnet, when it was presented to them, during that interruption of the circuit, which was deemed necessary to the production of electrical excitement.

725. The contact of another magnetizable body, a bar of iron for instance, was found to strengthen and preserve the opposite magnetic excitement, while a similar application would be destructive of the opposite electric excitement.

Fig. 35.



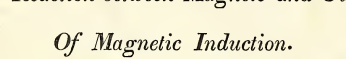
726. Under these circumstances, then, it never occurred to any one, that the magnetic poles could be influenced by electricity, whether galvanic, or mechanical, till Professor Oersted, in the winter of 1819, ascertained the existence of a reciprocal influence, between the magnetic needle, and a wire connecting the poles of a galvanic apparatus. In obedience to this influence, independently of terrestrial gravitation and magnetism, the former when freely suspended, was found to assume invariably a

position at right angles to the direction of the current, or more precisely, that of a tangent to a circle, concentric with, and at right angles to, the axis of the wire through which the current flows (742). Reference has been made to this wonderful reciprocal influence and the admirable galvanometrical invention to which it gave rise (306). It will be treated of more particularly under the appropriate head: *Reaction between Magnets and Currents* (731, &c.).

Of Magnetic Induction.

727. Magnetism has some analogy to statical electricity in the phenomena of *induction*, but utterly differs from it as respects *conduction*.

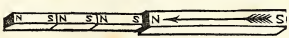
Fig. 36.



728. Thus the bar of iron B, figure 36, becomes magnetic, while in the vicinity of the permanent steel bar magnet M, precisely as B would be electrified by M, if previously charged by a machine: but, in the one case, there must be good insulation, while in the other none is requisite. The contact of M with B, would cause an electrical charge to be divided between them, whereas the same contact would cause the magnetic charge in B to be higher. In the one case the existing body loses power by contact, in the other it sustains no loss. That B is magnetized, may be shown by its attracting an iron nail or iron filings, if sufficiently near.

729. If several pieces of soft iron be placed successively in contact with each other, and with a steel magnet, as represented in the cut, figure 37, they will become magnets

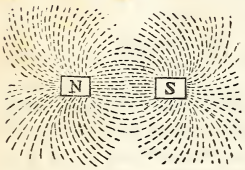
Fig. 37.



by induction, but will lose the property entirely if soon separated. Yet, a piece of iron kept for some time in a state of induced magnetism, retains the property to a certain extent, In proportion, as a steel bar is harder, it is less susceptible of receiving magnetism, but is more retentive of this property. On account of its superior retentive-

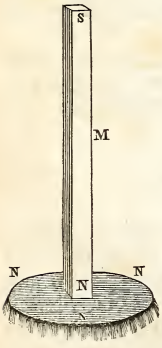
ness, all artificial magnets are made of steel, moderately hardened. Latterly our means of imparting magnetism to iron or steel have been immensely improved. A steel needle, or bar, may be permanently magnetized by drawing it, from one end to the other, over either pole of a powerful magnet. The magnetism at the end which moves towards the pole, becomes the opposite of the pole thus approached. If drawn from end to end in the same direction over the other pole, the magnetism will be enfeebled, if not destroyed or reversed; if contrarily, it will be confirmed, if not strengthened. Hence, there are two ways of producing the same results, *drawing similarly over the same pole, or dissimilarly over different poles.*

Fig. 38.



730. If while a U magnet is so situated as to have the poles uppermost, as represented in this engraving, a sheet of firm paper be placed horizontally over and in contact with them, on showering iron filings from a sand-box or sieve, they will arrange themselves as represented in the adjoining figure. Each particle of the filings becomes a magnet, having of course a south and north pole. The magnets thus created, arrange themselves in files, in consequence of the attraction between their oppositely magnetized extremities.

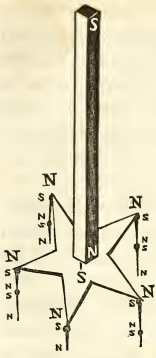
Fig. 39.



731. In the files thus formed by the inductive influence of the north pole of the U magnet, each little magnet will have its south pole the nearest, while in the files formed by the south pole of the U magnet, the files nearest the latter, will have their north poles nearest. Hence, the extreme ends of the files acquire opposite polarities, which are at the same time the opposite of those of the poles, with which they are respectively associated, and hence these extreme ends converge towards each other when sufficiently near.

732. Figure 40, serves to represent the magnetic power, given either to a disk or to a star of sheet iron, by applying to it at

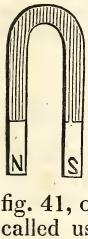
Fig. 40.



about its centre a pole of a magnet. By the polarity thus induced, several nails may be suspended as represented at N, N, N, N. To the disk a fringe of iron filings is attached. This power only endures so long as the magnet is applied.

733. If a prism of iron be attracted by a permanent magnet at either pole, the north pole for instance, the prism is converted temporarily into a magnet, acquiring at the place of contact a polarity the opposite of that of the pole to which it is presented. In other words, it acquires a south polarity, when it is presented to a north pole, a north polarity when presented to a south pole. Meanwhile, the other end of the prism acquires the same polarity as the pole by which the charge is effected. Hence, when in contact with two equally powerful bar magnets, as represented in figure 42, a prism of soft iron will be attracted with more force than the sum of their separate forces.

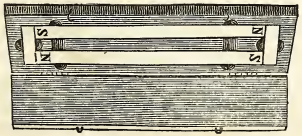
Fig. 41.



734. Further, if after having attached a prism of iron to the north pole of one bar magnet, and the south pole of the other, on bringing the two poles remaining free into contact with each other, or with a second prism like that above mentioned, the attractive power of the four poles will be more than twice as great as that exercised by either pair* when the others are without due communication.

735. Hence the superiority of the power of one duly magnetized bar in the shape of the letter U, fig. 41, over two bar magnets. A magnet, thus formed, is called usually a horse-shoe magnet, from its having some resemblance in shape to a horse shoe: but preferably on account of its greater resemblance to the vowel U, it has of late been called a U magnet, by Dr. Page, and others.

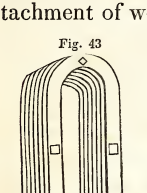
Fig. 42.



* Fig. 42, will convey a correct idea of two bar magnets as they are advantageously kept in a box with two armatures usually called keepers, on account of their sustaining the magnetic power when kept in contact with the poles as represented.

736. Agreeably to the statements above made, a prism of soft iron attached to both poles of a U magnet, reacts upon them inductively, so as not only to preserve, but to *heighten* their power, since it is found that when the weight appended to it is gradually increased, additional power is acquired to a certain point. On this account such a prism always accompanies a U magnet, and is called a keeper or armature. Some keepers have a hook to facilitate the attachment of weights.

Fig. 43



737. Thus the prism, A, figure 43, is the keeper or armature of the compound horse-shoe magnet to which it is represented as attached. The compound magnet, it will be perceived, consists of several U magnets so combined, that all the legs endowed with the same polarity are placed side by side. Thus associated, I have had a magnet to hold about nine times its own weight.

738. Under the head of magneto-electrical induction, it will be seen that compound magnets are the means of affording a convenient mode of subjecting patients to electrical discharges, somewhat peculiar in character, but of which, the effect upon the animal frame resembles the shock given by numerous voltaic series of small pairs.

REACTION OF MAGNETS WITH ELECTRICAL CURRENTS.

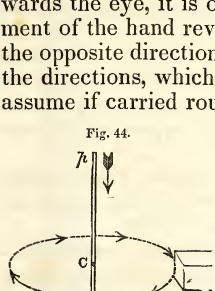
739. The student has been made acquainted with the deviations of a magnetic needle, when subjected to the influence of an electrical current. To this phenomenon it was expedient to make a premature appeal, as the means of detecting the currents resulting from galvanic or thermo-electric influence (306).

740. In order to form an idea of the positions relatively to an electrical current which a magnetic needle would assume could it be free from the interference of terrestrial gravitation and magnetism, let the student look perpendicularly on the pivot of his watch; let him suppose an arrow representing the needle, and the direction in which its north pole points, to be attached to the end of one of the hands, and at right angles to it, pointing in the direction

in which the motion usually takes place in clocks and watches. If a galvanic current be supposed to flow through a wire passing from the student's eye, through the pivot, the situations of the arrow, during one revolution of the hand, will give him an idea of all the positions which the needle, when carried round the wire, would assume, relatively to the galvanic current.

741. Supposing the current to be reversed, to flow towards the eye, it is only necessary to imagine the movement of the hand reversed, and the arrow head pointing in the opposite direction, to give an idea of the positions, and the directions, which the needle would then be found to assume if carried round the galvanized wire.

Fig. 44.



742. Suppose p, n, fig. 44, to be the axis of a circle C, and that a current is flowing through the axis in the direction of the arrows. The arrow heads in the circumference show the direction in which as many magnetic needles would point if exposed to no influence besides that of the current. When the current flows from N to P, the relative position of all the needles will be the reverse of those represented.

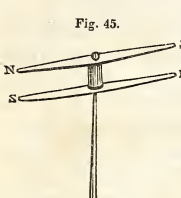
743. It is not possible to contrive any apparatus, which will illustrate the reactions of a current and needle, excepting the three instruments known severally as the compass, the astatic, or the dipping needle. These serve to illustrate the phenomena only when they take place in an horizontal or a vertical position. Yet from the results obtained in these, an idea may be formed of those which would ensue in any other positions in which needles could be situated.*

744. Figure 35, already given, represents the needle in the usual form. But the directive influence of the earth is avoided by associating two needles as in the subjoined figures, so that there is at either end a pole of each kind. If these be of equal energy, when thus combined reciprocal neutralization ensues, as respects their reaction with terrestrial magnetism. Such a needle is called astatic. When a galvanic current flows either above or below an astatic

* See engravings and descriptions of galvanometers.

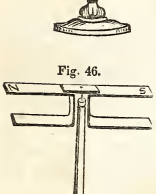
needle, excepting that as one of its needles will be somewhat nearer to the current than the other, its influence over them will be neutralized no less than the magnetic influence of the earth; but when the current is made to flow between the astatic pair, its influence on one, coöperates with its influence on the other.

Fig. 45.



745. Figure 45, represents an astatic needle, in which two magnets are so suspended, that there is a north and south pole at each extremity. By these means, if the needles are equally powerful, the influence of the earth on one is neutralized by its opposite influence on the other.

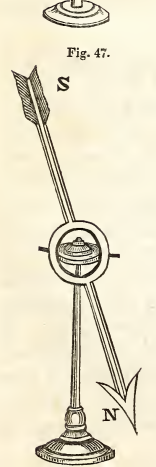
Fig. 46.



746. Figure 46, represents an astatic needle in another form, being made of two slender U magnets (735).

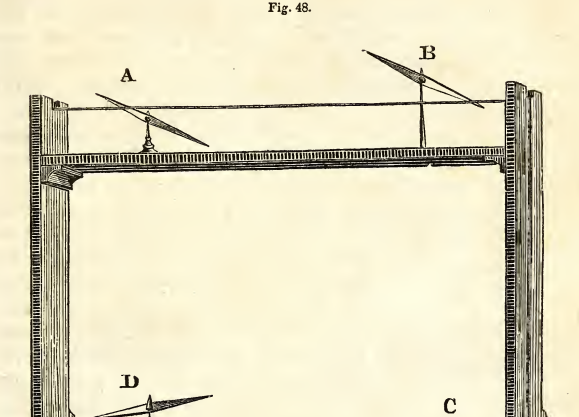
747. In the most sensitive galvanometers needles are preferably suspended by a hair or filament of glass, or of silk from a cocoon. By these means the influence of the earth over horizontal needles is neutralized. In another mode of suspension, the needle moves in a vertical plane so as to show that portion of the earth's influence which causes it to dip. An ordinary needle (35) being balanced on its pivot before charging, on charging and replacing it, the north pole in these latitudes will point obliquely downwards. This tendency it is requisite to balance by a counterweight, as it would interfere with the usual object of its indicating the north. But needles are made to indicate and measure this force. Figure 46, represents an instrument for the illustration of this property, which is called the dipping needle. The number of degrees which it deviates from a horizontal level, is called the magnetic dip.

Fig. 47.



748. The following engraving represents an apparatus, by means of which, four needles A, B, C, D, are simulta-

Fig. 48.



neously exposed to the influence of the same current, in respect to which they occupy different situations. Of any two needles, of the four, one of which is above the other below the current moving the same way, the poles will be seen discordantly directed. Of course any two of the four of which one is above the current moving one way, and the other below it, while moving the other way, will agree.

749. Accordance in the direction of needles exposed to the same circuit, is found only when the situation relatively to the current, and the direction of the current are alike, or where diversity in one respect is compensated by diversity in the other. In order that the currents thus moving in opposite directions should not counteract each other, it is necessary that two or three feet should intervene between those portions of the wire in which they take place.

750. The apparatus must, in order to show the phenomenon, have the wire in the plane of the meridian, so as to have the needles parallel to it; as, when uninfluenced

by the current, they place themselves so as to coincide with the meridian plane nearly, or, in other words, so as to point north and south.

751. The necessity which exists, of performing the experiment so as to avoid every injurious influence from terrestrial magnetism, ought not to create the idea that the phenomenon is dependent upon that magnetism. With astatic needles (44, 45), in which the polarity of one needle is so counteracted by that of the other, as to render the two indifferent to the polarity of the earth, the deviations may be produced without reference to the meridian.

752. The magnetism imparted to a coil by a galvanic current, agreeably to an observation first made by Ampère, was ingeniously illustrated by De la Rive, by causing such a coil to float together with the galvanic pair, of which it formed the connecting wire by means of a cork, as represented by fig. 49. C and Z are small plates of copper and zinc, above which the coil is supported, the ends being soldered severally to the plates. When the whole is made to float upon acidulated water, a galvanic current passes through the coil from the copper to the zinc plate. Under these circumstances the coil will react like a magnet with either of the poles of a magnet sufficiently approximated, so as to cause the whole apparatus to be apparently attracted or repelled.

Fig. 49.

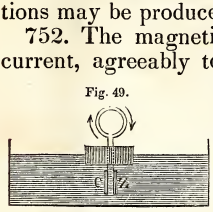


Fig. 50.

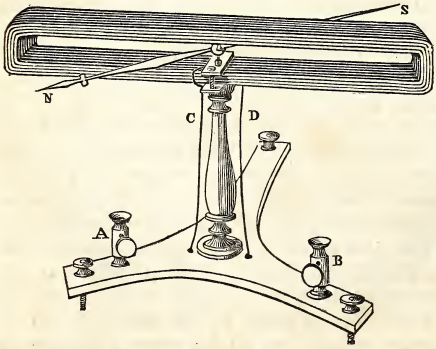
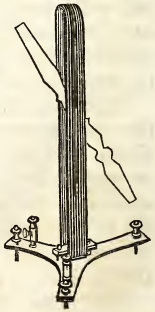
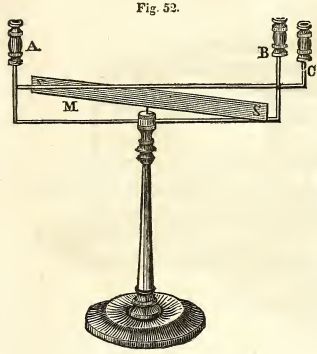


Fig. 51.



753. Two forms of the galvanometer (**50**, **51**), are illustrated by the preceding figures, one of which represents the situation of the needle when supported in a horizontal, the other in a vertical plane. Figure 51 corresponds with the dipping needle; figure 50 with the compass needle.

Fig. 52.



754. The rationale of these instruments may be made evident by the more simple form represented by figure **52**. In this the wire makes but one circumvolution, as in the larger apparatus, fig. **49**. The influence of the simple current being understood, it will be easy to conceive, that if the needle were subjected to two such circuits, the effect upon it would be arithmetically greater as the number of such circuits acting upon it from an equally favourable position. Consistently, Schweiger, by multiplying the circuits or circumvolutions, produced the famous instrument in question, appropriately called a multiplier as respects its origination, but not as to a designation of the use to which it is applicable.

755. In multiplying the circumvolutions, it is not necessary to multiply the batteries by which they are supplied, since, when formed of a continuous wire, the first and the last may, from the same battery, be supplied, if not exactly at the same time, with an interval almost infinitely small. Supposing each circumvolution to measure a foot in circumference, twenty-six hundred would be only half a mile, and this distance would be gone through in less than the five hundred thousandth part of a second, agreeably to the inferences of Wheatstone, supposing them applicable to currents of low intensity, as well as those of the statical kind.* For a galvanometrical instrument of the highest sensibility, see Melloni's thermo-multiplier, under the head of ***Thermo-electricity.***

* *Galvanometer or Multiplier of an unusually large size, made of Strips of Tin wound in a Coil with interposed Strips of very thin Paper.*

This engraving represents a large multiplier, or galvanometer, the needles of which are each about eighteen inches in length. The instrument is furnished above with a circle graduated into 360 degrees. Agreeably to the usual construction, the needle being within the coil, is subjected both above and below to the concurring influence of a current passed through the coil. Under these circumstances, the lower needle is situated in the apparatus represented by the adjoining figure. In the situation which the upper needle occupies, the influence of the lower portion of the coil, so far as it operates, must counteract that of the upper one. Yet when the lower portion of the metallic coil is at a distance from the upper portion of about one-third of the length of the needle, and this is situated very near to the upper portion as here represented, the influence of the latter may so far predominate as to render the indications very nice; while they are much more easily seen and estimated by means of the graduated circle, when, as in the situation of the upper needle, nothing intervenes between it and the eye.

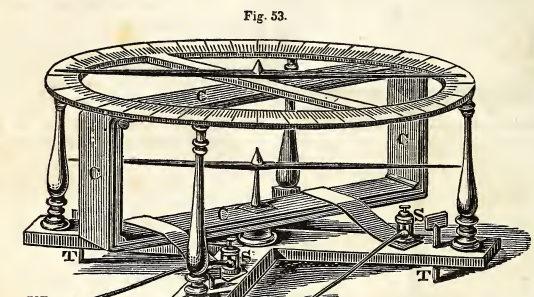
In another instrument of the same dimensions, I have used only a semicircle for the graduations, which, excepting the appearance, answers as well.

In lieu of wire, a coil of tin foil of about an inch in breadth, and eighty feet in

Ampère's Revolving Battery.

756. The most simple process for creating a rotary motion, by means of the reaction between an electrical current and a magnet, is that in which

Fig. 53.



length, separated by thin paper, may be used, but a copper wire of No. 16, and of about 180 feet in length, coated with shell lac varnish, will be more efficacious.

The coil of tin-foil or varnished copper wire, is wound about the parallelogram, C, C, C, C. The ends of the coil are severally soldered, or screwed, under the basis of the gallows screws, S, S.

When both needles are placed upon the pivot at the same time by the repulsion of their similar poles, they will diverge from the meridian unless they be in a reversed situation, in which case they will both appear as in the engraving, the north pole of one needle pointing north, the north pole of the other, south. When, under these circumstances, a discharge is made through the surrounding coils, the consequent movements are very striking.

The clean surfaces of disks of zinc and copper, each an inch in diameter, separated by paper moistened with pure water, are sufficient to move the needles sensibly. The wires, W, W, are used for the purpose of connecting the disks with the poles of the wires. They are attached to the instrument by gallows screws, S, S.

The level of the machine is preserved by the aid of four screws, of which only three can be seen in the drawing at T, T, T.

Rotary Movements arising from the Reaction between Magnets and Galvanic Currents.

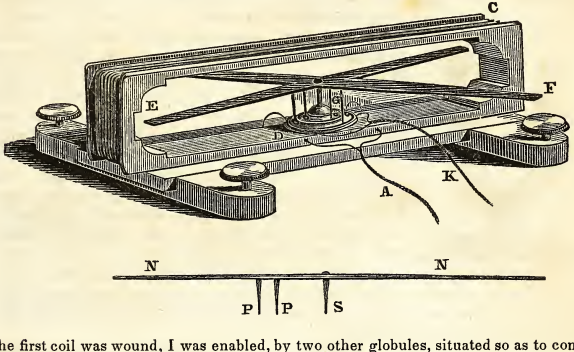
ENGRAVING AND DESCRIPTION OF A ROTARY MULTIPLIER,

Or one in which one or more Needles are made to revolve by a Galvanic Current.

The preceding engraving represents a rotary galvanometer, or multiplier, which I contrived in November, 1836, and which must have value as an addition to the amusing, if not to the useful implements of science. It is well known that by passing a temporary discharge through the coil of a multiplier, the needle may be made to perform a revolution, whereas if the current be continuously applied, the movement is checked as soon as the situation of the poles is reversed. To produce a permanent motion, the discharge must be allowed to take place only when the poles are in a favourable position relatively to the excited coil. This object I attained by means of two pins, descending from the needle perpendicularly, so as to enter two globules of mercury, communicating, on one side, with a galvanic pair, on the other with the coil of the multiplier. In the next place, by winding over the first coil, another of similar length, but in a direction the opposite of that in which

the galvanic triad, by which the current is generated, is made to revolve about the pole of a magnet, which serves as a support. This is exemplified by what has been called Ampère's rotating battery, of which figure 55, on the following page, will afford a satisfactory idea.

Fig. 54.



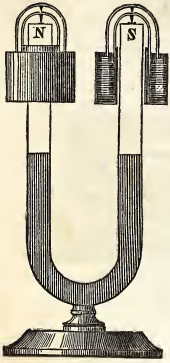
the first coil was wound, I was enabled, by two other globules, situated so as to communicate severally with the lower ends of the pins, at the opposite side from that on which the first mentioned globules were, to cause an impulse at every semi-revolution.

The one coil being wound to the right, the other to the left, the alternate effect of each upon the needle was similar in opposite parts of the orbits described by the pins. Lastly, a second needle, furnished with pins in like manner, being fastened at right angles to the first, so as to form with it a cross, as represented in the engraving, each needle is made to receive two impulses during every revolution. Hence one of Daniell's sustaining batteries, as made by Newman, is quite adequate to cause a revolution as rapid as consistent with a due degree of stability in the mercurial globules employed.

One end of each coil, by means of the branching wire A, communicates with one pole of the galvanic pair; the other ends of the coils terminate in mercurial globules contained in cavities on opposite sides of the wooden disc G, upon the centre of which the spindle of the magnetic needle rests. The branches of the wire K proceeding from the other galvanic pole, terminate in globules situated in the vicinity of those above mentioned, so that as the needles revolve, the pins proceeding therefrom perpendicularly may touch a pair of the globules first on one side and then on the other. Whenever this contact takes place, the circuit is completed, and a discharge is effected through one or the other of the coils of the multiplier.

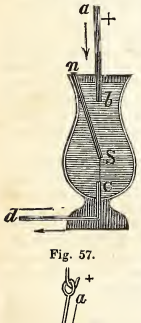
Supposing E and F to be north poles, a discharge through one of the coils will cause E to move off a quarter of a circle, or more. As this ensues, the pins of F will come in contact with the globules which those of E touched before. Of course F will be propelled so as to cause the pins of E to reach the pair of globules at G, which, completing the circuit of a coil wound in a way the opposite of that first mentioned, concurs with that coil in its influence, so as to promote the rotation previously induced. The same result ensues when the pins proceeding from F, come in contact with the globules situated at G, and when E returns to its original starting point. It follows that by a repetition of the process the galvanic action is sustained. The phenomenon is as well illustrated by employing the single needle, N, N, as by two, but the most pleasing and energetic effect is produced by the crossed needles. In this simple form the spindle on which the needle rests and revolves is represented at S; the pins at P, P. Each coil, consisting of copper bell wire, is about thirty feet in length, and is contained in the groove C. The frame of the multiplier is constructed of mahogany, and is levelled by the milled headed screws, on the ends of which it is supported.

Fig. 55.



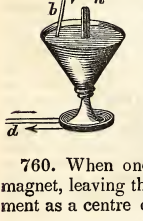
757. Two concentric cylinders of sheet copper, one about three-eighths of an inch larger than the other, are united by a flat ring of the same material, so that the latter forms a bottom, while there is between them an interstice of three-eighths of an inch. The inner cylinder is open and furnished with an arch of copper, at the summit of which there is a pivot pointing downwards. This pivot rests upon an agate cup seated upon one of the poles of a steel magnet. By means of another arch of copper a cylinder of zinc is supported within the interstice, resting by means of an appropriate pivot on a little concavity in the lower arch above described, as supporting the copper cylinders. Upon the other pole of the magnet another similar apparatus of cylinders is supported. When the apparatus is to be put into operation, the interstices between the copper cylinders must be supplied with a diluted mixture of nitric and sulphuric acid. A galvanic current taking place in each little battery through the supporting arches from the copper to the zinc (320), the cylinders revolve, the zinc and copper in opposite directions, as respects the movement of the two batteries, the similar cylinders move oppositely, the dissimilar cylinders move alike.

Fig. 56.



758. A magnet, *n s*, being attached, as in figure 56, by a silk thread, to the centre in the bottom of a cup of mercury, so as to float in that metallic liquid, a wire, *a b*, is fixed over it vertically, so as just to enter the mercury for a small depth. The metallic support of the wire is connected with one pole of a galvanic battery, the mercury with another. In this case, the upper end of the magnet, while swimming in the mercury, revolves about the wire from right to left, or from left to right, accordingly as the poles of the magnet, or the connections with the galvanic apparatus, may be varied. If, on the other hand, the magnet be made immoveable, while the vertical wire is upon a universal joint, the wire will revolve about the magnet, and be liable to change its direction, in the same way, as the moveable magnet was actuated, with respect to the wire.

Fig. 57.

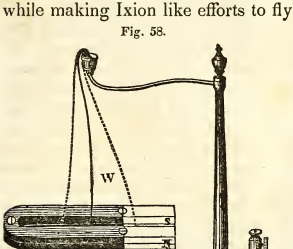


759. The letters *n* and *s*, and direction of the arrows, in either of the adjoining figures, representing the apparatus alluded to, show the relative situation of the poles of the magnets, and direction of the current requisite to produce a revolution from right to left. In either apparatus a reversal of the relative position of the poles, or of the direction of the currents, will reverse the rotary motion. Of course *n* designates the north, and *s* the south pole.

760. When one end of a wire is fastened to the axis of the pole of a magnet, leaving the other end free, it will revolve about the point of attachment as a centre of motion, and in like manner, if the magnet is fastened

at one end to a point in the axis of the wire, the free end will revolve about the wire, because in either of the cases, whether it be that of the wire or magnet, an escape from one point of collision existing in the circle, throughout which the conflicting influence prevails, only carries it to another such point. Thus the point of attachment, about which the motion takes place, becomes a centre, about which either the magnet or the wire revolves, while making Ixion like efforts to fly from inevitable collision.*

Fig. 58.

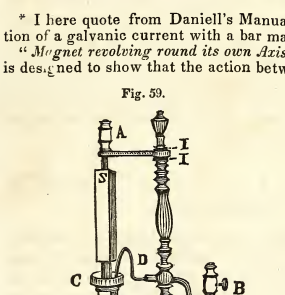


761. Let the end of the wire W hanging from a metallic bracket, which communicates with one of the set screws on the right of the platform, enter some mercury, occupying a cavity in the latter, which has a metallic communication with the other set screws. Under these circumstances, as soon as the set screws are connected with a galvanic battery in operation, the end of the wire flies out of the mercury, but the circuit being thus broken, the end of the wire soon falls again into contact with the mercury, and from the same cause as at

* I here quote from Daniell's Manual a very interesting illustration of the reaction of a galvanic current with a bar magnet.

"*Magnet revolving round its own Axis.*—The instrument represented in figure 59 is designed to show that the action between the current and the magnet takes place equally well when the magnet itself forms the conductor of the electricity. The lower end, N, of the magnet, being pointed, is supported on an agate at the bottom of a brass cup connected under the baseboard with the binding screw cup, P. The upper end, S, is hollowed out to receive the end of the wire fixed to the cup, A; the brass arm supporting this cup is insulated from the brass pillar at I, I, by some non-conductor of electricity. To the middle of the magnet is fixed a small ivory cistern, C, for containing mercury, into which dips the end of the wire, D. Thus the magnet is supported with its north pole downwards, and is free to rotate round its vertical axis. A little mercury should be put into the cavity at S, and into the brass cup at N, and the ivory cistern be filled sufficiently to establish a connexion between the magnet and the wire, D.

Fig. 59.

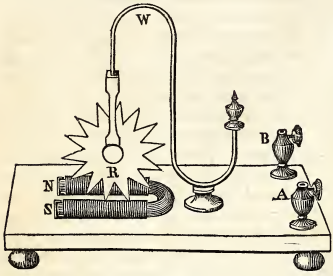


"On connecting the cups, A and B, with the battery, the current will flow through the upper half of the magnet, causing it to rotate rapidly. If the cups, B and P, form the connexion, the current will traverse the lower half, equally producing revolution of the magnet. Now connect A and P with the battery, and no motion will result, because the electricity passes through the whole length of the magnet in such a manner, that the tendency of one pole to rotate is counteracted by that of the other to move in the opposite direction. Connect B with one pole of the battery, and A and P both with the other pole. The magnet will now revolve, since the current will ascend in one-half of its length, and descend in the other."

first, again flies out. Thus an alternate motion is produced and sustained as long as the current is continued.

Barlow's Revolving Wheel.

Fig. 60.



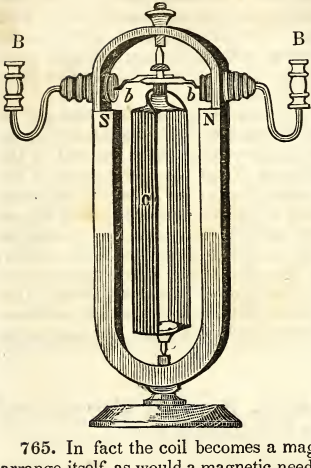
762. The apparatus represented by figure 60, is called Barlow's revolving wheel, from the name of the inventor, the wheel being situated between the jaws, either of a steel magnet or an electro-magnet, and made the medium of the galvanic current, any tooth in contact with the mercury in the cavity under it, is actuated in the same way as the wire in the experiment above described (762). But when agreeably to the same law, one tooth flies from collision with the magnetism, another takes its place, and of course encounters the same treatment. Every tooth being sucsessively affected in like manner, the wheel revolves as long as the current endures. It is not necessary to the motion that the circumference be serrated, but it serves to make a pretty spark at each contact. The endurance of light thus arising, is too brief for the wheel to make a perceptible movement while it lasts. Hence, when the instrument is illuminated only by its own scintillations, it appears to be at rest, however rapidly it may revolve. It is computed that eight sparks in a second give the effect of a continuous illumination, and as the wheel gives more than these, it appears as if seen by a continuous light.

Explanation of the Motions produced by means of the Apparatus described in the three preceding pages.

763. It has been shown, that the reciprocal reaction between a magnetic needle free to move, and a wire transmitting a galvanic current, is such, that the former will strive to assume a position at right angles to a line parallel to the axis of the wire. Of course, as action and reaction are equivalent, the wire, if free to move, while subjected to the influence of a stationary needle, or other magnet, will arrange itself so as to produce the same relative position between the two bodies as when the wire is stationary, and the needle free. But if freedom of motion exist only at one extremity, whether of the needle or the wire, the motion can only take place at that extremity. Yet if the movement hence arising be not such as to interrupt the galvanic current, or be such as to permit its renewal as soon as discontinued, the consequent movement must be continued or repeated, and may be productive of rotary motion, as in the case of figures 54, 55, 56, 57, 59, or of alternate motion, as in the instance of 58.

Revolving Rectangular Coil.

Fig. 61.



764. As in the galvanometer of Schweiger, the force of the conflict between the dynamic polarity of the current, and the stationary polarity of the needle, is multiplied by reiterating the presence of the former in the coiling of wire through which it has to pass, in order to perform its circuit, so the instrument of which figure 61 is a representation, is an apparatus in which a current transmitted through the rectangular coil, between the jaws of the magnet, is made to react with the magnetic influence of the latter, and strives to escape therefrom, in order to assume the position in which there will be least interference. This takes place when the plane of the coil is so situated as to be at right angles to a line passing through the centre of each pole.

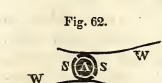
765. In fact the coil becomes a magnet, (752,) and of course tends to arrange itself, as would a magnetic needle similarly situated; but, by means of a contrivance called the pole changer, described below, in making a semi-revolution to effect this arrangement, the direction in which the current goes through it is reversed, and consequently a different impulse is received, causing another semi-revolution. No sooner is this made than the impulse again changes. Thus a continuous revolution is produced as long as the current endures.

Of Page's Pole Changer.

766. In some cases, in order to produce opposite impulses, it is necessary to cause a galvanic current to flow alternately in opposite directions, in others, as it will hereafter be seen, it is an object to render an alternating current constant in its direction. For these purposes the following contrivance was devised by our countryman, Doctor Page, and executed by Daniel Davis, jr., the highly ingenious artist, to whom we owe the successful fabrication of a variety of electric, galvanic, and electro-magnetic apparatus.

767. The apparatus in question being employed to reverse the polarity of the electro-magnet in the apparatus last described (767), the following explanation is given in reference to the use of it therein made. The pole changer, figure 62, consists of two small segments of silver S, S, fixed on opposite sides of an axis of which a section is represented in the figure. These pieces are not in contact, and are sufficiently insulated from each other, and from the axis. Of the two ends of the coil, situated between the legs of the magnet as represented, one is soldered to each segment. By means of a wooden arch, of which the polar ends S, N, of a U magnet are the abutments, two

Fig. 62.



wire springs, *b*, *b*, are so supported and insulated, that through the intervention either of two cups of mercury, or two set screws, at B, B, they may be made to communicate at pleasure with a galvanic battery. The free ends of these wires are made to press against the segments of silver with sufficient force to make a good contact. The arrangement is such, that the respective contacts of the semi-cylinders with the springs will take place when the coil C is, as represented in the figure, at right angles to a plane passing through the axes of both legs of the magnet.

768. The apparatus being thus prepared, let the mercury cups and of course the wire springs, be in communication with a competent battery, consequently the current will from one semi-cylinder, enter one end of the coil, proceed through the circumvolutions of the latter, and go out of the other end of the coil to the other semi-cylinder; but if the coil be turned half round, the segments, and the ends of the coil attached to them respectively, will have their electrical states simultaneously reversed, creating in the sides of the coil a corresponding change of electro-magnetic polarity. Thus when the coil is turned from the position into which the polarities would bring it, in seeking to regain that attitude, it reverses them. This causes it to make another half revolution, which equally operates to reverse the propensity to change, and thus rotary motion is induced as long as the current is sustained.

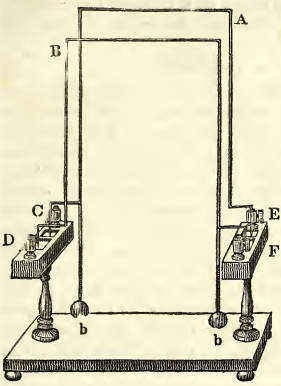
Attraction and Repulsion between Electrical Currents and the Movements thence arising.

769. Not long after Oersted's discovery, it was ascertained by Mr. Ampère, a French philosopher of celebrity, to whose inventions and theoretic suggestions, electro-magnetism is pre-eminently indebted, that wires, completing the circuit of different galvanic batteries, would attract and repel each other; but not in a mode analogous to electrical reaction, since it was between the bodies, similarly excited, that the attraction was observed, while the repulsion took place between bodies dissimilarly excited. Electrical indications are obtained only, when the poles of the generating apparatus are unconnected, those afforded by the galvanized wires, were the consequence of their connecting the poles of the galvanic apparatus.

770. Figure 63, represents an apparatus, contrived for the purpose of shewing the reaction between wires subjected to galvanic currents.

771. Two copper wires, A, B, are supported parallel to each other, in such manner as that their upper parts may move freely towards each other, so as to touch, or in the opposite direction so as to become more remote. These wires are supported on points, which rest on the bottoms of cavities replete with mercury, being amalgamated so as to insure a perfect contact with that metal. By means of the little metallic balls, b, b, which may be lowered or raised by screwing, the centre of gravity of the wires may be so adjusted as to keep them perpendicular, when undisturbed, and yet

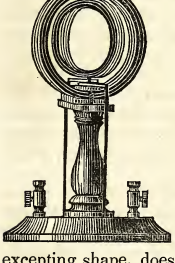
Fig. 63.



render it easy for them to oscillate from a very slight impulse. The four cavities holding mercury within which the points rest, as above stated, have each a metallic communication with the set screws C, D, E, F, when E, F, are made to receive wires from the same pole of a battery, while the other two, C, D, communicating with the other pole, the current will go the same way through both of the wires. Under these circumstances they will attract each other, and come together; but if E and C, be made to communicate with the one pole, while D and F, communicate with the other, the current will flow oppositely in the wires, and they will move apart, as if actuated by repulsion. If the wires be made to oscillate by a timely opening and of closing the circuit, the motion will be increased.

Rotation of one Coil of Wire within another, in consequence of the rapid creation and reversal of the Polarity arising from the change of direction in a Galvanic Current caused by Page's Pole Changer.

Fig. 64.



772. The adjoining figure 64, is designed to illustrate by means both striking and agreeable, the powerful and rapid attraction, and repulsion, between wires caused by electrical discharges made through them alternately in opposite directions.

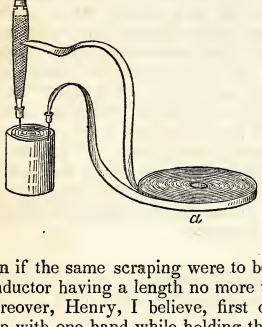
773. This apparatus has a close analogy with that already described figure 61, as to the means by which the polarity of the coil is imparted, and the direction reversed at every semi-revolution, by means of a galvanic current, and the pole changer (767). We have only to substitute for the U magnet and rectangular coil, two circular coils of the same material as the rectangular coil. Of the two coils, one is large enough to contain the other without touching, and being stationary, takes the place of the U magnet. The other, excepting shape, does not differ from the rectangular coil; while it is perfectly similar, as respects the means by which it is supported on an axis and associated with the semi-cylinders of the pole changer, and the office which it performs. In one case by polarities arising from a current, the rectangular coil is made to rotate by conflicting with the poles of a U magnet; in the other case the polarities arising in a circular coil from the same cause, conflict with those arising from a current in another coil. In either case seeking a non-conflicting attitude, it is disappointed by the consequences of its own efforts, and the perverting influence of the pole-changing apparatus.

Of Electro-dynamic Induction.

1st. Under this head we may put Induction of a Current upon itself.
2d. Generation of Currents by the Dynamic Inductive Influence of other Currents.

Induction of a Current upon itself.

Fig. 65.



774. Figure 65 represents a ribbon of copper, in weight thirteen pounds, in width one and an half inches, in length ninety-three feet. This ribbon is wound into a flat coil, of sixteen inches in diameter, but, being insulated by a double coating of silk, there can be no metallic contact between any of its circumvolutions. When one end of the coil thus formed, is, as represented, connected with one pole of an active battery *e*, to the other pole of which a rasp *d*, is soldered; on scraping the rasp with the free end of the coil, sparks and metallic deflagrations ensue with much more energetic scintillation and louder snapping noise, than if the same scraping were to be performed with the termination of a conductor having a length no more than requisite to complete the circuit. Moreover, Henry, I believe, first observed, that an operator touching the rasp with one hand while holding the end of the coil during the scraping, would be subjected to a perceptible shock at each of the interruptions of the circuit, to which the sparks were indebted for their existence.

775. Under the circumstances of the experiment, described in the preceding paragraph, whenever the ribbon touches the rasp, the battery has two circuits at command, one completed altogether by the coiled ribbon, the other in part by the person of the operator. Yet on account of the low intensity of the current, the imperfectly conducting circuit formed by the animal frame, will not be the mean of a perceptible discharge so long as the other route afforded by the perfectly conducting copper ribbon is uninterrupted: but when the ribbon circuit is ruptured, a perceptible discharge takes place through that made up of the operator's person, the coil which he holds, and the rasp which he touches.

776. By the premises, the direct action of the battery is wholly incompetent to produce any perceptible discharge through the operator. Consequently the shock, produced as described, and all the other characteristics in which the phenomena arising from the breach of the circuit when the coil is interposed, differ from those which appear when a short metallic conductor is similarly employed, must be ascribed to the intervention of the coil. It would seem, therefore, that the materials of the coil, both ponderable and imponderable, become coerced by the battery into an unnatural state; so that, on the rupture of the circuit to which this state is due, the matter recoils towards its natural equilibrium, producing an electric discharge of an intensity far above that of the parent stream sent through the coil from the battery. On this account, it would seem as if the resulting discharge might be appropriately designated as a recoil current. That the conductor, which is the channel of a galvanic current, is in an artificial

state of polarization, almost the whole of the phenomena of electro-magnetism seems to justify. This state, noticed by Faraday, was designated by him as an electrotonic. The tension arising from this state, or the energy of the effort to have it made by the matter in which it has been produced, appears to be greater when the conductor, being in the ribbon form, is wound up as a coil. Doubtless the proximity of the circumvolutions to each other, must cause a reaction between the similar polarities, tending to augment their resistance to the state imposed on them by the battery.

777. Analogous to the accumulation of power, above described as created within the ribbon coil, is that which arises in a voltaic series of sufficient intensity when the circuit is incomplete. Hence, agreeably to Henry's observations, the direct action of a series of high intensity, forming a circuit through a short conductor by sudden contact, resembles, as to intensity, the indirect action of a battery of low intensity, on breaking the circuit formed through a long conductor. In the one case, the intensity being due to the resiliency of the electrifiable particles of the conductor, is increased with its length to a certain point; in the other case, the intensity being due to the battery, the conductor cannot be too short: excepting that when the effect is measured by the current inductively created in another conductor, agreeably to the process next to be explained, this effect must be influenced by the length of the conductor, as well as the intensity of the current which it conveys.

778. It has been suggested (776), that the electrical discharge accompanied by a shock and unusually large and noisy spark which characterizes the process under consideration, is the consequence of the sudden effort of the matter of the coil, both ponderable and imponderable, to recover its natural equilibrium from a state of forced polarization within the coil. There is a rough analogy between this resiliency of the supposed imponderable current, and that which would ensue, if, instead of a copper coil dynamically electrified, a steel watch spring were wound up, to a certain degree of tension, and then suddenly liberated so as to be allowed to react.

779. But in the act of recoiling, if, by the discontinuance of the broad channel in which it may be generated, the current be diverted into a collateral channel, in which it must experience far more resistance, the animal frame of the operator, in the case in point, the concussion must be proportionable to the impediments, just as if a torrent by being suddenly dammed up, were forced into a circuitous channel, containing rocky obstructions.

780. In the instance of a principle, which moves with the inconceivable velocity which characterizes electrical discharges, the larger the mass which recoils, the greater the effect; but as to wind up a spring instantaneously, requires an activity in proportion to its length, the longer the wire in which the tension is to be induced, the greater the voltaic intensity required. Thus Henry found, that when a voltaic series, consisting of six pieces of bell wire, each one inch and an half in length, and an equal number of pieces of zinc, of like dimensions, were employed to excite a due electrical tension in a spool of wire five miles long, and one-sixteenth of an inch thick, the shock resulting from resiliency on the rupture of the circuit, was sufficient to affect twenty-six persons joining hands.*

* I quote here from Davis' Manual of Magnetism, an engraving and description of an instrument designated as the *Contact Breaker*. Supposing to employ this mechanism in the production of the phenomena, arising from a rapid rupture and renewal of a galvanic circuit, this explanation may be desirable to some of those who may witness the processes in which it may be used.

Generation of Currents by the Dynamic Inductive Influence of other Currents.

781. The power which an electrified body has to produce an opposite charge in another, has been explained under the name of "*Electrical excitement by Induction*" (E, 107). There is another species of inductive influence, to which allusion was made as dynamic induction (E, 120).

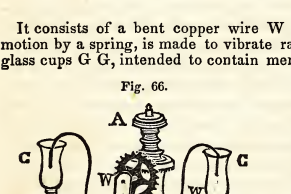
782. The attractive and repulsive influence of wires subjected to galvanic currents has been illustrated (771–2). To Faraday we owe the discovery, that there is such a reaction between the cause of electricity in any one conductor, with the same principle in another, that under favourable circumstances a current in one may inductively produce a transient current in the other. Thus, when two long wires were associated in concentric coils, metallic contact between the circumvolutions being prevented by the silk with which the wires had been covered like bonnet wire, on making or breaking a galvanic circuit made through one of them, a transient current was produced through the other. This effect was detected by subjecting a needle to the dynamic discharge through a small hollow helix of wire, included in the resiliating circuit.

783. The following laws have resulted from Faraday's researches:—

"1. During the time a galvanic current is increasing in quantity in a conductor, it induces, or tends to induce, a current in an adjoining parallel con-

It consists of a bent copper wire W W, which by means of clock-work set in motion by a spring, is made to vibrate rapidly, dipping its ends alternately into the glass cups G G, intended to contain mercury. The spring is wound up by turning the milled head A. The glass cups are open at the bottom to allow the mercury to come in contact with the brass pillars into which they are cemented. These pillars are both connected with one of the binding screw cups C C; the other cup communicates with a brass mercury cup P, into which dips a short wire connected with the vibrating wire. Sufficient mercury must be put into the cup P, to keep the end of the vertical wire covered, and enough into the glass cups to allow one end of W W to leave the mercury in its cup a little before the other end dips into its portion.

Fig. 66.



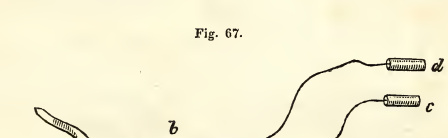
The Contact Breaker may be advantageously used in connexion with many of the instruments for affording sparks and shocks, which will be described under the following head. The current must be transmitted through the two instruments in succession, by connecting one of the cups C C with one pole of the battery, and the other cup with one of those attached to the spiral or other piece of apparatus, the remaining cup of which is to communicate with the other pole of the battery. It is better to break the circuit mechanically in this way, than by means of any interrupting apparatus worked by the battery itself, as a considerable part of the power of the current is then expended in giving motion to the interruptor.

On making connexion in this manner with a flat spiral, and turning the milled head A to put the vibrating wire in motion, a brilliant spark will be seen at each rupture of contact, accompanied by a loud snap, and producing considerable combustion of the mercury. With a battery consisting of a few pairs of plates of large size, such as Dr. Hare's Calorimotor, the size of the spark will be greatly increased and the snap become as loud as the report of a Leyden jar. The shock will also be pretty strong, and may be increased by covering the mercury in the glass cups with a stratum of oil. A shock may be obtained, especially when oil is used, on closing the circuit as well as on opening it, though inferior to that given in the latter case; a faint spark is also sometimes seen when the wire dips into the mercury.

ductor in an opposite direction to itself. 2. During the continuance of the primary current in full quantity, no inductive action is exerted. 3. But when the same current begins to decline in quantity, and during the whole time of its diminishing, an induced current is produced in an opposite direction to the induced current at the beginning of the primary current."

784. Professor Henry, of Princeton, has shown that currents may be strikingly produced by induction, in the following manner. The circuit formed, through the ribbon coil, *a*, with the battery, figure 65, being alternately made and interrupted, as stated (774), a helix of coated copper wire of about 21 wire gauge, and of about 4900 feet in length, is subjected to the inductive influence of the coil, as represented in the adjoining figure, in

Fig. 67.



which the coils and helix are situated concentrically one upon the other, while separated by a plate of glass. The intensity of the resiliating current as measured by the shock, increases with the length of the helix employed, until the resistance to the electrical current consequent to the length, compensates the benefit otherwise arising. Yet, as might be expected, the length to which the circuit may be thus extended with advantage, ceteris paribus, is proportional directly to the numerical extent of the voltaic series employed (431).

785. The ends of two wires severally connected with those of the helix, being rubbed one against the other, while the circuit through the coil is alternately broken and renewed in rapid succession, sparks will be visible, and slight shocks may be felt through the fingers or tongue, on contact with the wires. When the ends of the wires are joined, the sparks and snaps, which can be obtained between the end of the coil connected with the battery while passing over the rasp, are much diminished in energy, and no shock can be received.

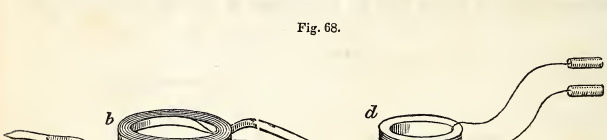
786. A delicate galvanometer being associated in the circuit with the upper coil, whenever the battery circuit is completed through the coil, the magnetic needle will be extensively deflected, but will immediately return to the meridian, a flow of a current through the wire of the galvanometer is thus indicated, which is nevertheless transient apparently. On opening the circuit, a similar transient deflection will occur in the opposite direction. No deflection occurs while the battery current is flowing steadily. The galvanometer should be placed at such a distance from the coil that the current through this may not affect the needle.

787. A sewing needle will be magnetized if placed within a spiral of wire of very small diameter, duly comprised in the same circuit as the helix. The polarity produced by the current which ensues on the completion of the circuit, will be the reverse of that communicated by the current consequent to its rupture. If both currents are allowed to act on the

needle, it will acquire little or no magnetism, as the magnetizing influence of one will counteract that of the other.

788. Instructed by Faraday, Prof. Henry has added many ingenious discoveries respecting the phenomena of dynamic induction; among these is the consistent consequence, that the transient secondary current, as above described, inductively produced in a second coil, was capable of being communicated conductively, so as to circulate through a third coil, which, acting inductively on a helix, was productive of a tertiary current of the same character, though feebler, as that produced when the helix is exposed to the inductive influence of the primary coil. Hence shocks will be received by

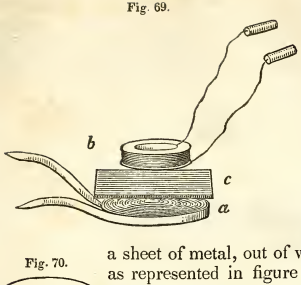
Fig. 68.



a person holding in each hand one of the handles, to which the ends of the helix are attached, as represented in figure 68. The process may be extended so as to produce, analogously, fourth and fifth currents. "Henry alleges that a shock was given, by means of a current of the third order, to twenty persons joining hands." Shocks extending to the arms were also produced by the process above mentioned, "with currents of the fifth order."

789. Of course, the characteristic efficacy of the primary current must be liable to vary with those of the galvanic apparatus employed in its production, and the length, width, and thickness of the ribbon employed. With a simple elementary battery of a given size, there must be a certain length, width, and thickness of ribbon, which will produce a maximum effect; and any deviation from this combination of requisites must be productive of deterioration. It follows, that with ribbons of various dimensions, there must be for each a degree of intensity and quantity depending on the number and size of the voltaic pairs, which will render the inductive power produced by its means, a maximum. Hence the sectional area and length of the ribbon, the extent of the oxidizable surface of the zinc, and the number of the series into which it may be divided, form variable elements, susceptible of an almost infinite variety of complications. Each of these various complicate combinations must have its appropriate effect upon a secondary coil, having a given length and sectional area, but must vary with every change in either of these dimensions. In like manner, the characteristics of the current produced by the inductive influence of a second, a third, a fourth, or a fifth coil, or as many as may be employed with effect, must vary with their length, shape, and sectional area. Another source of variation arises from the distance of the inducing coil from that which is the subject of the inductive power, and also their parallelism, and the degree in which their axes may approach or recede from coincidence with one line. The directions of the currents, inductively incited, seems to have varied with the distance.

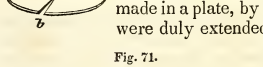
Fig. 69.



790. To Prof. Henry is due the detection of the screening power of metallic sheets. I allude here to the fact, that the interposition of a metallic sheet, as in figure 69, between the ribbon and coil, or between a coil and a helix of fine wire, nearly annihilates the power to produce shocks, although the interposition of a plate of glass, or any other *non*-conducting material, does not impair the inductive influence. Yet a sheet of metal, out of which a gore or sector has been cut, as represented in figure 70, does not impair the power of induction. Moreover, when from the corners of the gash made in a plate, by cutting out the gore, wires soldered thereto were duly extended and attached to the ends of a helix, including a needle; to this needle, on subjecting the plate to the inductive influence of a coil duly excited by a battery as in the adjoining figure, polarity was imparted, which was such as to show the resilient current to be in the same direction as that in the inductive coil, *a*. This resilient current is considered by Henry as a secondary one, but it seems to me it is to the impalpable current of which it is the resiliating effect, that the appellation of secondary should be applied.

Fig. 70.

Fig. 71.



791. I find that a sheet of zinc does not prevent the creation of a resiliating current in my helix (793), sufficient to affect the gold leaf galvanoscope. I am under the impression that the plate acts by causing a diffusion of the inductive force, so as to reduce its intensity too low for causing a shock.

792. The screening power above described, as displayed by a sheet of metal interposed between the first and second coil, equally availed, when a like interposition was made between a second and a third, a third and a fourth, or a fourth and a fifth coil.

793. When a copper ribbon coil is made to act inductively on a long helix of wire, as illustrated in figure 67, the shock arising from the resiliency of the induced electrical tension seems, within an extensive boundary, to be greater in proportion as the wire is longer and more slender. I have employed a ribbon coil of about three inches and a half wide, and one hundred and ninety-six feet long, and a helix of coated copper wire, No. 21, of about twenty-eight pounds in weight, and a mile in length, furnished with bright metallic handles. Although the helix may be supported at the distance of several feet above the coil, while the current of a calorimotor is alternately established and arrested within it, a person holding one handle of the helix wire in each hand, will receive shocks which augment in severity as the helix is approximated to the coil, and become intolerable when it is brought into contact with it nearly.

794. Figure 72 represents a helix such as described, situated as when it gave smart shocks, in consequence of the inductive resiliating influence of the coil, *c*.

Fig. 73.

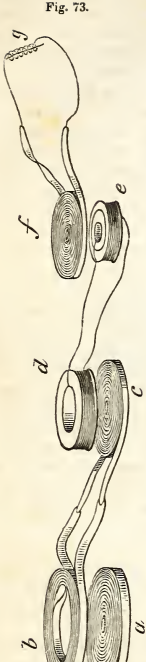
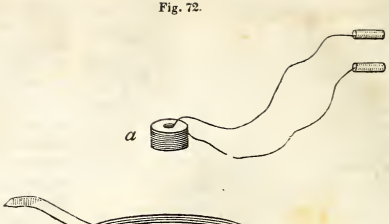


Fig. 72.



795. From the preceding statement, it appears that a current of great *quantity* may produce a resilient current of great intensity. But Henry has ascertained that the converse is possible. The adjoining figure has been employed by him to illustrate the experiments by which the facts alluded to were established.

796. The tension *induced* by coil *a*, in coil *b*, is transmitted *con*ductively to coil *c*, whence it acts *in*ductively upon the helix *d*, producing intensity, and is *con*ductively transmitted to *e*, whence it *in*ductively generates a current of *quantity* therein, sufficient to magnetize a needle included in a little spiral of wire as represented.*

797. Much labour has been bestowed by Henry in determining the directions of the current in the different coils; but in this part of his investigations there is too much abstruse and minute detail, but little connected with striking phenomena, to be introduced into a text-book. I am under the impression, that following out the consequences which theory would suggest, founded on the idea that each current, inductively produced, must be the opposite of that which immediately induces it, would give the direction of each current generated in the coils and helices of figure 73.

Dynamic Inductive Influence of Statical Electricity.

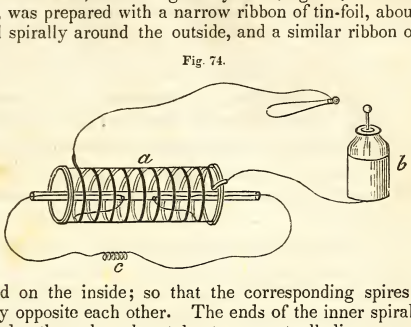
798. On this subject I will quote a few lines from Henry's Memoir in the American Philosophical Transactions, together with the appropriate engraving.

799. "The discovery of the fact that the secondary current, which exists but for a moment, could induce another current of considerable energy, gave some indication that similar effects might be produced by a discharge

* It must be evident, from the experiments here illustrated, that the same inductive power produces either quantity or intensity, accordingly as it is made to act in the long and narrow circuits afforded by the wire helices, or the shorter and more ample channels afforded by the ribbon coils.

of ordinary electricity, provided a sufficiently perfect insulation could be obtained. To test this, a hollow glass cylinder, fig. 74, of about six inches in diameter, was prepared with a narrow ribbon of tin-foil, about thirty feet long, pasted spirally around the outside, and a similar ribbon of the same

Fig. 74.



length pasted on the inside; so that the corresponding spires of the two were directly opposite each other. The ends of the inner spiral passed out of the cylinder through a glass tube, to prevent all direct communication between the two. When the ends of the inner ribbon were joined by the magnetizing spiral, *c*, containing a needle, and a discharge from a half gallon jar sent through the outer ribbon, the needle was strongly magnetized in such a manner as to indicate *an induced current through the inner ribbon in the same direction as that of the current of the jar.* This experiment was repeated many times, and always with the same result.

800. "When the ends of one of the ribbons were placed very nearly in contact, a small spark was perceived at the opening, the moment the discharge took place through the other ribbon.

801. "When the ends of the same ribbon were separated to a considerable distance, a larger spark than the last could be drawn from each end by presenting a ball, or the knuckle.

802. "Also, if the ends of the outer ribbon were united, so as to form a perfect metallic circuit, a spark could be drawn from any point of the same, when a discharge was sent through the inner ribbon."

803. An analogous inductive influence to that observed in the case of a series of coils, of which the first in the series is made the channel of a galvanic discharge, has been noticed by Henry in the case of wires placed nearly parallel to each other, of which one is made the medium of a discharge from a battery of coated jars. Having, with my assistance, caused two such wires to pass round my lecture room, as near as possible to each other, without touching, the ends of one of the wires being severally inserted in cups of mercury, while the other wire was the medium of a discharge from my battery, shocks were received in the fingers when they were plunged in the mercury in the cups, at the moment of the discharge.

804. It is to discharges of this kind, as I conceive, that the souring of milk and beer, during thunder storms, may be ascribed.

805. It is not possible to do full justice to the speculations, experiments, and observations of Henry, in an elementary treatise: I therefore forbear to extend this account of them further.

806. As respects the hypothetical explanation, I have resorted, in common with Henry, to the conventional idea of electrical currents inducing other currents; but it will be hereafter suggested, in treating of the theory of electricity, that the phenomena may be the effect of waves of polarization

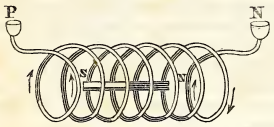
induced in that ocean of the imponderable material cause of electricity, which, in a state of excessive condensation, is conceived to occupy the space intervening between ponderable metallic particles, and at the same time in a state of greater or less density to pervade the creation.

INDUCTION OF MAGNETISM BY CURRENTS.

807. Soon after Ampère, in observing the reaction between electrical currents, made the first step in the branch of science last treated of, discovery was made of the power of such currents to impart magnetic polarity to a coil of wire, and of rendering a needle situated transversely to the current, magnetic.

808. This power of imparting polarity, was prodigiously increased, when the wire wound into a helix, was made to include the needle. By these means the influence of the current was reiterated, as in the instance of Schweiger's galvanometer.

Fig. 75.



809. The adjoining figure represents a right spiral of copper wire, containing a rod of soft iron. The ends of the wire terminate within small cups of mercury. Thus situated, a discharge of the galvanic fluid through the spiral cannot be made so transiently as not to impart magnetism to the bar. The current being from the cup, P, to the cup, N, the poles of the rod will have the character indicated by the initials, S and N; but either reversing the current, or substituting a left spiral, would reverse the character of the magnetism communicated to the rod.

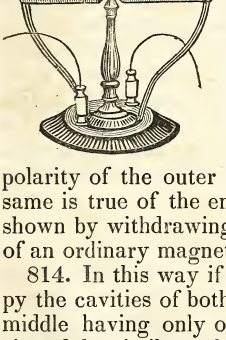
810. The polarity given to the needle, when the current flowed one way, was found to be the opposite of that imparted when it flowed in the opposite direction. The current being conceived to proceed in the wire from positive to negative, the end of the needle pointing the same way, as the flowing of the current must receive north polarity, the other receiving consequently south polarity; but reversing the direction of the current, the polarity must be reversed. The polarity varied also, as the helix was wound to the right or the left, so that a left helix being used as mentioned above, the currents would have effects the opposite of those produced by a right helix.

811. In fact the same wire was found to acquire differ-

ent polarities, when different parts of it were made to occupy a succession of cavities in different helices, some wound to the right, the others to the left. A needle was magnetized when situated on the outside of a galvanized helix, but much less powerfully than when included discharges of statical electricity were found competent to produce magnetism, when substituted in the same processes, for those of galvanism, but the power imparted was comparatively very feeble.

812. Mr. Ampère, besides other interesting discoveries which my limits will not allow me to illustrate, and which it would be impossible to describe satisfactorily, most ingeniously caused the ends of a wire forming a helix to return through the axis of the helix, without touching it, to the middle, and, passing them out of the helix, one on one side, the other on the other side, they were made to form an axis, on which the whole might revolve. The different ends of the wire, thus arranged, being made duly to communicate with a galvanic battery, the helix was influenced by a magnet, as one magnet is affected by another.

Fig. 76.



813. Two coils wound one to the right, the other to the left, as in figure 76, and made the medium of a galvanic current, in the usual way, will impart opposite polarities to two bars or rods of iron simultaneously introduced, one of them within the coil on the right, the other within that on the left. The polarity of the outer extremities will be similar, and the same is true of the ends near the centre. This may be shown by withdrawing and presenting them to the poles of an ordinary magnetic needle.

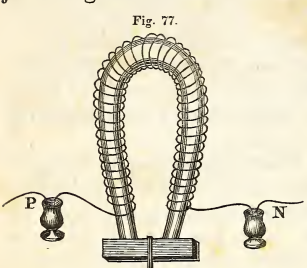
814. In this way if one bar be introduced so as to occupy the cavities of both spirals, it will have three poles, the middle having only one polarity, which will be the opposite of the similar polarity of the extremities.

Of the Electro-Magnet.

815. A rod of iron, magnetised by a galvanic current, as above illustrated, is called an electro-magnet. Professor Moll perceived, that if a bar magnet was more powerful in the horse-shoe form, the same ought to hold in the

case of an electro-magnet. Hence he was led to construct an electro-magnet resembling that represented in the subjoined figure.

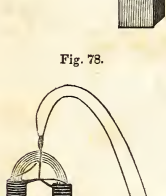
Fig. 77.



816. It consists of an iron rod in the shape of a horse shoe, on which copper wire, of the size used for bells, covered by silk, is wound, from one end to the other. His electro-magnet thus made, held seventy-five pounds, while weighing itself only five pounds.

817. The quantity of wire employed in the construction of the electro-magnet represented by the preceding cut is evidently inadequate to produce a high charge, yet the engraving may be more competent to convey a due conception of the process by which such a magnet is charged, than that of figure 78, which is closely covered with copper bell-wire, so as to be capable of acquiring from the same current proportionably much higher power. Of course it must be imagined that the cups at N and P, figure 77, are to be supplied with mercury, so as to make a connexion with the extremities of a galvanic battery. Yet I prefer set screws, for effecting such connexions.

Fig. 78.



Of Henry's Electro-magnet.

818. The results obtained by Moll were eclipsed by those accomplished by our countryman, Professor Joseph Henry, of whom mention has already been made.

819. Of his celebrated electro-magnet, the following account is extracted from Silliman's Journal, vol. 21, 1831, page 400.

820. "A soft iron bar, two inches square, and twenty inches long, having the edges rounded, was bent into the form of a horse-shoe. Five hundred and forty feet of copper bell-wire were wound round it, in nine coils of sixty

feet each. These coils were not continued from one end of the magnet to the other, but each of them was wound round a portion of the horse-shoe about an inch in length, leaving the ends of the wires projecting, and properly numbered. The alternate ends were soldered to a copper cylinder, and the others to a small cylinder of zinc, containing only two-fifths of a square foot, and forming a voltaic arrangement with dilute acid. When the armature of soft iron was placed across the ends of the horse shoe, it was found capable of supporting 650 pounds: an astonishing effect for so small a battery, which required a charge of only half a pint of dilute acid. With a larger battery, the weight sustained was 750 pounds, which seemed to be the maximum of magnetic power that could be developed in that bar by voltaic electricity. It is remarkable, that when the ends of the wires were united so as to form a continuous wire of 540 feet, the weight raised was only 145 pounds."

821. Another magnet was made by Professor Henry, which held upwards of two thousand pounds.

822. Subsequently magnets have been made adequate to hold three thousand pounds.

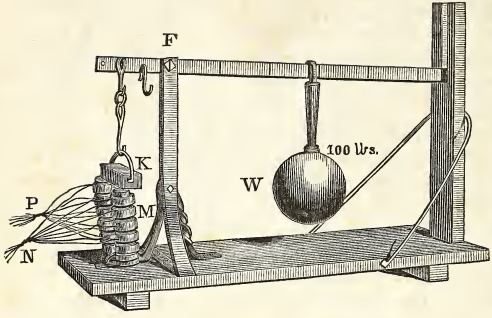
823. As soon as the current through the coils of an electro-magnet is arrested, the keeper, if loaded, falls off, since the magnetic power which remains, is extremely feeble. The rapidity with which the magnetic polarity is produced, destroyed, and reproduced, or reversed by shifting the direction of the current, is very remarkable.

824. The following figure represents a modification of Henry's electro-magnet, as constructed by me, soon after the account above quoted was published.

825. M is the electro-magnet, consisting of an iron cylinder, of 1¾ inches in diameter, and 24 inches in length, bent so as to form a U. It has six coils of sixty feet of covered copper wire on each leg. K, the keeper, of which the sectional area should not be less than that of the bar of which the electro-magnet is formed. The keeper is suspended from a steelyard, divided into parts, each equal to the distance between the hook supporting the keeper and the pivot of the fulcrum at F. The iron globe W, weighs 100 pounds, and when slid to the fifth division necessarily acts on the keeper with a force equal to five times its weight. When excited by a calorimotor of two pairs, such as has been described, fig. 8, it has been necessary to add additional weight to increase the force to 750 pounds, before the separation of the keeper could be effected.*

* The coils are twelve in number, each comprising sixty feet of copper bell-wire, wound up with thin paper and shell lac varnish, to prevent metallic contact. They

Fig. 79.



Of the Rapidity with which Polarity may be Reversed, and the consequent Rapidity of Rotary Motion thence arising.

826. The attractive power above mentioned as imparted by an electrical current to a cylinder or bar of iron in the U form, is rendered more surprising by the inconceivable minuteness of the time requisite for the production, and reversal of the polarity on which it depends.

827. The alternations of attraction and repulsion resulting from the reversal of polarity, has been an object of much attention and experimental contrivance, with the view of obtaining an advantageous moving power for machinery.

828. Previously to the career of Professor Henry, it was known that the most transient duration of a galvanic current passing through a helix would magnetize, or reverse the magnetism of an iron rod contained within the helix. This susceptibility of opposite magnetization was more fully presented to attention by Henry, and may be illustrated by a little machine, of which a description is subjoined.*

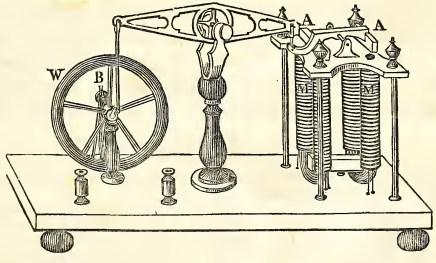
were severally wound upon an iron cylinder of the same diameter as that of the electro-magnet, previously surrounded with thick paper so as to increase the bulk a little. In consequence of this precaution the bore of the coils was sufficiently capacious to allow them to be transferred with ease, from the iron cylinder to the legs of the magnet. Six were thus affixed to each leg. In order that such a set of coils should coöperate, when all are wound one way, so for instance, as to form right coils, all the beginnings must communicate with one pole, all the endings with the other. To facilitate this, the analogous extremities are soldered together as represented at P and N. The same rule must be observed if they be all wound to the left. Yet, a right and a left coil, may be made to coöperate in producing the same polarity, if each beginning is applied to the same pole as each ending. By a beginning, I mean that extremity at which the coil is begun to be wound: by an ending, of course, that extremity at which the winding terminates.

* *Reciprocating Engine.*

Figure 80, may afford a good idea of a reciprocating machine working upon the principle suggested by Henry. The polarity of the two upright electro-magnets M,

829. *Davenport's Machine*, which drew so much attention, added nothing to our knowledge. The change from an alternate to a rotary motion, was an easy step made independently by Richie and others, as well as himself. As respects its efficacy as a moving power compared with an alternating motion, it was a step towards the rear, which any one well acquainted with the nature of the peculiarity of the powers of electro-magnets and with mechanics, would not have taken. In my opinion, the great defect of this power is, that its force is exerted through a very minute space. For its advantageous exertion it is requisite that the surfaces of the armature and those of the poles of the electro-magnet be parallel and exactly opposite. These objects cannot be well obtained when either the armature or the magnet are undergoing a rotary motion. In that case, when the position of the masses actuated by the opposite polarities, is most favourable for the exercise of their reciprocal attraction or repulsion, their position is least favourable for the production of circular motion. It is in

Fig. 80.



M, is established or nullified alternately, as the fly-wheel in revolving makes a communication with the coil of one or the other, by a mechanism called the *break piece.* The little cylindrical rod which forms the axis of the fly-wheel W, is filed away at two places of about a quarter of an inch in width, on opposite sides of the rod, leaving between them, a part which is not deprived of its rotundity. Of three springs proceeding vertically from beneath the base board, so as to be held firmly by it, one communicates by a wire beneath the board with the set screw on the right and through it with a pole of a battery. Pressing at the same time on the intermediate round portion of the axis, it keeps it constantly in the same electrical state as the pole of the battery with which it communicates. Each of the other two springs communicates through the wire of one of the helices M, M, with the left set screw, and through this with the other pole of the battery. The axis, as above mentioned, being in constant communication with one pole, the current alternately passes through the helix of one or the other electro-magnet, accordingly as the spring with which it communicates is, or is not, in contact with the axis in consequence of the alternate presentation at every semi-revolution of the portion which has been removed by the file or that which has been left in *statu quo.* As the portions in the last mentioned state, are on opposite sides, the contact of the springs with the axis, is alternate. Thus each magnet is alternately charged and alternately free. Consequently two keepers of soft iron associated with each other, and with a beam crank and fly-wheel, by being alternately attracted and liberated, undergo an alternate motion which is imparted to the beam. This motion by means of the crank causes the fly-wheel and its axis to revolve, and thus gives efficacy to the mechanism of the break piece.

It follows that the machine continues in motion as long as the galvanic current is applied.

The analogy between the mechanism of this apparatus, and that which is resorted to in steam engines, is self-evident.

the vicinity of the "*dead point*," so called technically, that there is the most intense reaction.

830. Davenport's apparatus did not differ essentially from that of Richie. In both, the alternation of polarity by which the beam was set in motion agreeably to the apparatus last described, was made to act upon an electro-magnet turning on a vertical axis between the jaws, either of a permanent magnet or of an electro-magnet. The former was employed by Richie, the latter by Davenport. I have been under the impression that Richie did not make due acknowledgment to Henry, for the hint afforded by the alternating beam engine. Yet De la Rive alleges that he saw an apparatus, in 1828, which had been contrived by Richie, to revolve by the alternation of polarity, resulting from changes in the direction of the galvanic current.*

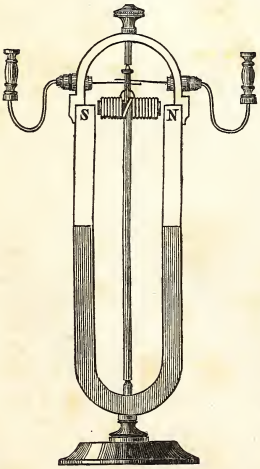
On the great Advantage of Electro-magnets as the Means of imparting Permanent Magnetism.

831. One of the practical advantages arising from the art of making electro-magnets is, that we are enabled to impart instantaneously the most powerful magnetism to steel bars. The mode of employing for this purpose an electro-magnet, does not differ from that already described

* *Richie's Revolving Electro-magnet.*

The following figure will give an idea of the apparatus which in Europe is known as Richie's revolving electro-magnet.

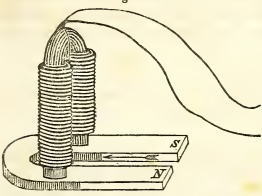
Fig. 81.



Two cups of mercury, or two set screws, are supported severally on each side of an arch of brass, by means of wires terminating each in one of the springs of a pole changer (767). By these means the helix in the electro-magnet is subjected to a current from a battery, of which the direction is reversed as often as the electro-magnet accomplishes a semi-revolution. If, while subjected to the current the electro-magnet be made to turn through a quadrant, so as to be at right angles to the position in which it is represented, each of its poles will be attracted by one pole and repelled by the other pole of the U magnet, between the legs of which it is placed. Hence, as soon as liberated, it will seek to arrange itself so as to obey the polar impulses alluded to. But in being thus impelled, it acquires a rotary force which carries it so far as to have the current reversed by the pole changer. It is now impelled to reverse its position, but at half a turn encounters a change of polarity from the same causes as at first. Thus a rotation ensues and endures so long as the current is supplied. I have seen the electro-magnet supported horizontally upon the vertical axis as represented in the preceding figure, revolve so rapidly, as to make a humming noise, and to assume the appearance of an obtuse spheroid or turnip-shaped disk.

in using the permanent magnet for the same purpose (729). In either case, however, when the magnet to be charged is of the U form, the induction is more powerful if an electro-magnet having the same distance between the legs is employed. As the coil may be made loose enough to slip on and off (825), rods of iron in the U shape, may be provided so as to suit the various permanent magnets required.

Fig. 82.

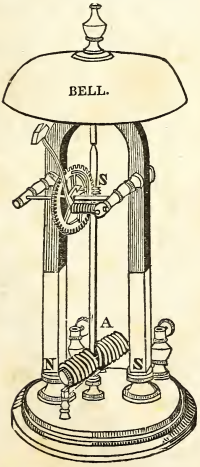


832. Figure 82, will serve to illustrate the proper position of the electro-magnet relatively to a steel U bar to be magnetized, as when first applied. It is to be slid from the position in which it is represented, towards the ends of the steel U bar, two or three times; and finally being brought into the situation of a keeper, let the keeper be applied before the magnet is slid off.

Dynamic Gold Leaf Galvanoscope.

833. The figure of the gold leaf galvanoscope was introduced, in treating of the galvanic circuit, in order to give the student an idea of the means which it affords of detecting a galvano-electrical current. The explanation of this instrument, requiring a reference to the laws and phenomena which fall under the head of reaction of magnets with electrical currents, was postponed in order to be given here, the figure being of necessity reinserted in the next page.

Fig. 83.—*Rotating Engine Bell.*



834. Between the legs of a U magnet, fig. 84, a glass tube is placed, to each end

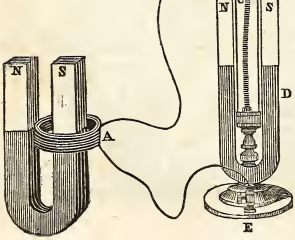
Figure 83, represents the revolving magnet, as associated with a bell, by means of a wheel-work, like that of a clock. An endless screw S, on the axis acts upon the teeth of a wheel, which as it revolves by means of a projecting pin, lifts the handle of a hammer until it arrives at a due elevation, where it is released from the pin. Then by the reaction of a spiral spring, the hammer is make to strike the bell. As the wheel has sixty-four teeth, it takes sixty-four revolutions of the magnet to cause one stroke. In some instances the number of strokes in a given time being ascertained, the revolutions were found to amount to more than one hundred in a second.

of which a brass cap is fitted, supporting within the tube forceps so affixed, as to be concentric with the axis of the tube. Between the forceps thus supported and another similar pair affixed to the lower cap of the tube, a strip of gold leaf is extended, of which one of the two ends is so held by each forceps, as to make it occupy the central space about the axis of the tube between the forceps. The caps communicate with set screws, to which wires are to be affixed, to complete any circuit, which is to be tested. When subjected to a very feeble galvanic discharge, the gold leaf will, agreeably to the law above stated (626), endeavour to quit the position which it holds, in order to take the tangential attitude, and while thus striving to escape from between the jaws of the magnet, inclines one way or the other, in a plane at right angles to one passing through the axes of both jaws (740).

Of the Induction of Electrical Currents by Magnetism, or Magneto-electrical Induction.

835. The influence of electric currents in inducing magnetism, having been fully demonstrated, the celebrated Faraday was led to inquire whether the converse might not be attainable. Accordingly he has ascertained, that electrical currents may be induced by magnetic action. As, on the one hand, an electrical current circulating through a coil of wire will produce magnetism in an iron bar situated within the coil, so, on the other, if a bar previously magnetized be alternately introduced into the coil, and withdrawn, currents will be induced in the coil at each ingress and egress of the bar. To the currents thus induced, as well as to those already described as resulting from the inductive influence of the current in one helix producing a current in another in its vicinity (781), the appellation of Faradian has been given in honour of their discoverer.

Fig. 84.



836. The inductive influence of a magnet, in causing an electrical current, may be illustrated by the process which the adjoining figure exemplifies. It will be perceived, that the gold leaf of the galvanoscope, already described (757), is made, as represented in the engraving, to complete the circuit of a coil of covered copper wire, which has been so wound as to leave about its axis a va-

cant space sufficient to receive either of the legs of a U magnet.

837. In putting the coil into the situation in which it is represented, the gold leaf will incline one way; on removing the coil, it will incline the other way: moreover, the flexure which arises on putting the coil on one leg, will be the opposite of that which will ensue when it may be put about the other leg. Yet removal from one leg, and placing it about the other, will be productive of a similar flexure. While the coil is stationary, the gold leaf is not affected. It is only during the changes of its situation relatively to the magnet, that any electric impulse is given adequate to the production of a transient current (633).

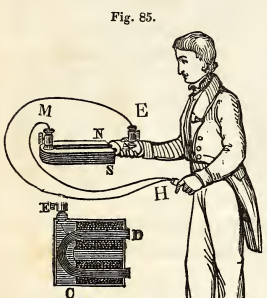
838. It has been pointed out that each end of the keeper of a magnet assumes a magnetic polarity opposite to that of the pole with which it may be in contact, but that the magnetism thus acquired, ceases on the removal of the keeper from the magnet. If we suppose such a keeper to be surrounded by a coil of insulated wire, we have only to remove it from its appropriate position, and restore it alternately, in order to produce a Faradian current within the coil at each change of position (835).

839. Under these circumstances, the magnetism of the keeper is destroyed as often as it is removed from the poles, and restored as often as it resumes its appropriate position; and an alternate accumulation and subsidence of the magnetic fluid within the keeper, is supposed to produce Faradian currents by its reaction with the electric matter in the wire.

840. The current produced by this last mentioned process was detected by Faraday, by causing the ends of the wire coiled about the keeper to communicate with the terminations of the coil of a multiplier, at the moment of removal from the poles of a powerful magnet. But of the current thus detected, indications were soon after obtained by the production of sparks. This interesting result was first attained by the distinguished Italian electricians, Nobili and Antinori, by causing the ends of the wire coiled about the keeper to break contact with each other through the medium of an amalgamated surface, in consequence of the jar arising from the lifting of the keeper from the poles of a magnet. Professor Forbes, of Edinburgh, produced

the same phenomenon shortly afterwards, by employing the same process with a powerful loadstone.

Fig. 85.



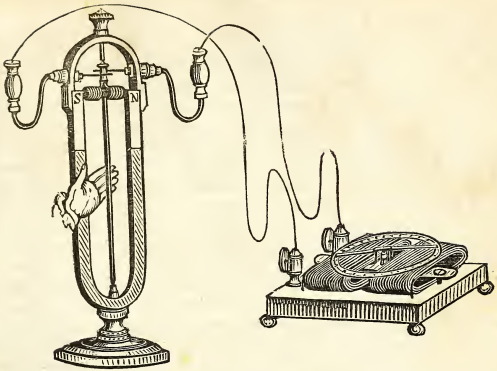
841. This experiment is illustrated by the adjoining figure. The armature is a U bar of soft iron, and is surrounded by a fine wire coil of great length. It may, advantageously, be fifteen hundred feet long. Of course it has the customary covering of cotton or silk. A section of it, and its case, is represented at E, O, D. One end of the wire is soldered to the armature and the case. The other end of the wire is soldered to the set screw, E, insulated from the case by ivory. H, held by the operator, is a metallic handle with two wires; one is attached to the set screw, E, and thus communicates with one end of the coil; the other communicates with the coil through the set screw, M, communicating with the magnet, and of course with the keeper, whenever it is in contact with the poles of the magnet. When the keeper is applied to the magnetic poles, it becomes a magnet (733); when separated, it returns to its previous state. The internal change which the keeper undergoes in acquiring or losing polarity, is productive, by induction, of cotemporaneous currents in the coil. The resiliency of the polarized matter in the keeper, when it is suddenly put on, or pulled off from, the poles of the magnet, acts like that of a galvanic circuit when suddenly opened or closed (775). Hence, simultaneously with the removal, a sensation and a spark is perceived by the operator, who, when the circuit through the magnet is suspended, becomes the only medium through which the resilient secondary current (779) can pass. The current passes from the case to the right hand, and through his left, and the wire to the other end of the coil.

842. The changes of the relative situation of the keeper and magnet, by which the current within the coiled wire is excited, and arrested and reversed alternately, were much facilitated by a mechanism contrived by Pixii, of Paris, which caused the rapid rotation of a magnet near to a keeper, surrounded by a coil of wire. But, by Saxton, an obviously advantageous improvement was made, in causing the keeper to revolve instead of the magnet.

843. In consequence of the greater rapidity with which the reversal of the positions of the keeper could be accomplished by the aid of bands and multiplying wheels, the magneto-electric machine thus contrived by Pixii, and improved by Saxton, not only produces deflections in the needle, and a succession of sparks which seem to have no intermission, but likewise severe shocks, the ignition of wire, and chemical decomposition.

844. If Richie's revolving electro-magnet, as modified by Page (81), be connected with a galvanometer, as represented in the adjoining figure, on causing the axis and electro-magnet which it supports to rotate, at every semi-revolution in the needle will be observed a deviation, which will alternately be opposite in direction.

Fig. 86.

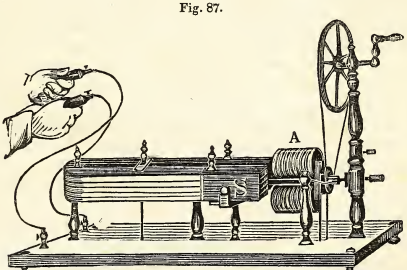


845. This phenomenon is perfectly analogous to that to which attention is in the next place to be given, in which a current is produced at every alternation of polarity of an iron keeper, consequent to the reversal of situation relatively to a permanent magnet.

Of the Magneto-electric Machine.

846. The following figure represents Saxton's magneto-electric machine, as well constructed by Daniel Davis, jr., of Boston.

Fig. 87.



847. A, represents the armature of this apparatus, supported on an axis, so as to be as near as possible to the terminating surfaces of the legs of a compound magnet. Of this axis one end reaches between the legs parallel to and equidistant from them, to a socket in the arched part. The other end of the axis, furnished with a pulley, terminates in another socket beyond the armature; so that, by means of a wheel and band, it may be made to revolve with great celerity.

848. The iron of the armature forms three sides of a rectangle. On the two opposite sides, 2500 feet of copper wire, of a grain to the inch in

weight, are wound so as to involve each side of the rectangular keeper in a coil.

849. It has already been explained, that an armature becomes a magnet by induction, so long as it is applied to its magnet; but that its polarity ceases when it is removed, or may be induced in the opposite way by the reversal of its position relatively to the magnet (733).

850. Now these changes all ensue during every semi-revolution, and during the shifting of the polarities a corresponding change is induced in the surrounding coil, equivalent to what is called an electrical current. The coils, when their ends are in communication, have produced within them alternate circuitous discharges, having all the attributes of those which occur within the active galvanic circuit.

851. The process is the converse of that which takes place in Richie's revolving electro-magnet, fig. 81. In that apparatus, alternations of opposite magnetic polarities are produced by alternations in the direction of an electrical current; in the magneto-electric machine, alternations of opposite electrical currents are produced by alternations of opposite magnetic polarities. This must be evident from the preceding illustration (829).

852. To obtain shocks from this machine, a toothed wheel attached to the axis, is connected with one of the extremities of the wire surrounding the keeper, the other end of this wire communicates with one of the set screws of the board, a spring of metal attached to an upright column of brass, plays upon the teeth of the revolving toothed wheel, and communicates with the other set screw. Any portion of the animal frame, being made to complete the circuit between the set screws, will receive a shock, arising from a resilient current, at each interruption of the circuit caused by the intermission of contact between the spring and teeth, as it leaps from one tooth to the other.

853. When cylinders of copper, soldered to the ends of the coil surrounding the keeper of a powerful magneto-electrical machine, are grasped firmly with the hands previously moistened, the most powerful man is unable during the action of the machine to relax his hold, he is placed at the mercy of the operator controlling the wheel of the machine.

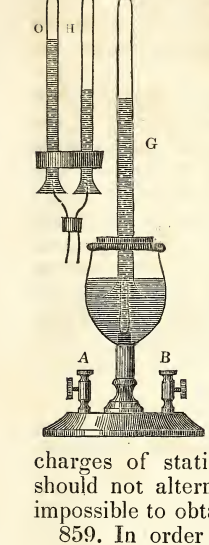
854. Experience has shown that, for the production of the shock, the wire coiled about the keeper should be of comparatively great length, say fifteen hundred feet, but for producing ignition, should be much stouter, and not more than eighty feet in length. The propriety of making this difference of length, Mr. Saxton assures me, was first suggested by him.

855. Mr. Clark, of Adgar street, near the Adelaide Gallery, London, applies the keeper to the magnet on one side, near the ends of the legs, so that in his electro-magnetic machine the magnet is vertical, whereas in Saxton's it is horizontal. A priori, this would seem to promise no advantage, and yet machines thus constructed have proved at least as powerful as any others. The only advantage which I can conceive of, as resulting from this arrangement, is, that the movement of the keeper is in a direction tending to confirm the polarity of the steel magnet.

856. The magneto-electric machine has been resorted to as a remedy for nervous, rheumatic, and paralytic affections; and at all events may be of use as a medicina mentis, which probably will do no harm, even when it does no good. It has a great advantage over common electrical machines, in being independent of the weather, and is preferable to voltaic apparatus in not requiring the use of corrosive liquids. The apparatus may be carried in a box, without detriment, by land, as well as by water.

Magneto-electric Electrolysis.

Fig. 88.



857. The process by which the decomposition or electrolyzation of water, is accomplished by the currents induced by a magneto-electric machine, may be understood from the annexed engraving. Two wires proceeding from their solderings to the set screws A and B, may be observed to reach vertically into the trumpet-shaped orifice of the tube G, which is situated over them, and which must be at the outset replete with water.

858. It has been mentioned that to obtain the intensity requisite to severe shocks, the circuit is abruptly broken by a toothed wheel, while otherwise it would continue until the keeper should be off of the magnet. But this secondary current is not sufficiently enduring to be competent for electrolysis. In this respect it resembles discharges of statical electricity. Moreover, the current should not alternate in direction, as this would render it impossible to obtain the different elements separately.

859. In order to cause the electricity to flow always in the same direction, a pole changer, like that already described, must be employed. For the same reason that a current otherwise uniform in its course, may by this pole changer be made to flow alternately in opposite ways, so where a current is alternately opposite, the pole changer may render it uniform in its course. The change of position of the silver segments which convey the currents to the set screws, to which the electrodes of the battery are affixed, and the change in the direction of the discharges taking place simultaneously at every semi-revolution, if a segment begin with the reception of a positive discharge, it must receive the same at the end of a half turn, and of course the set screw with which it communicates and any conductors thereto attached. All this is equally true of the segment which receives at the outset a negative discharge.

860. To effect the collection of the elements of water separately, it is necessary to employ two tubes O, H, one of

the wires acting as electrodes, being introduced into each. In this case as in others, the ratio of the bulk of the hydrogen to the oxygen, will be indicated by the space respectively occupied by them. With a good machine, to evolve a cubic inch of a mixture of both gases, may require between five and ten minutes.

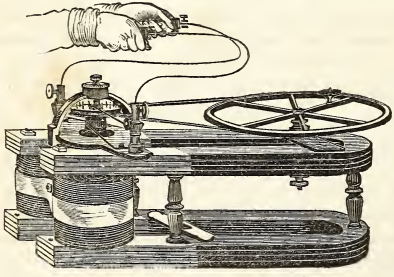
Fig. 89.

861. By the primary current of a magneto-electric machine, various saline solutions may be decomposed. For this purpose a tube in the shape of the letter U may be employed, figure 89, a pledget of cotton cloth may be made to occupy the bend, as a partition. The solution occupying each leg of the tube will give proof of its decomposition by appropriate tests. Any salt with a metallic radical which does not decompose water per se, will deposit the metal on the negative electrode. Hence this process may be employed in gilding or silvering by electrolysis.

Improved Magneto-electric Machine.

862. Since the preceding descriptions were written, I have received from Mr. Davis, a magneto-electric machine, upon a construction which is evidently new, and of which the effects are very energetic.

Fig. 90.



863. It will be perceived, that in Saxton's machine, 80, the keeper is a soft iron bar so bent as to form three sides of a rectangle A, B, C, of which the two opposite sides B, C, may be designated as legs. Each leg is enclosed in a helix of covered wire. The end of each leg is acted upon by one pole of a compound magnet, the side intermediate between the legs serves only to be a mean of communication between them, having no ability to heighten the magneto-inductive influence.

864. But in the new instrument, a second compound magnet is made to

take the place of the inactive part of the rectangular keeper; so that two compound magnets are made to co-operate, to impart an opposite polarity by their application, at four extremities of two bars, instead of two extremities of one, equivalent to two, usually employed.

865. Of course each of the iron cylinders which takes the place of the legs of a rectangle in Saxton's construction, are presented to poles endowed with an opposite magnetic power. The north pole of the lower magnet is thus made to co-operate with the south pole of the upper one, and in like manner the south pole of the upper magnet with the north pole of the lower magnet, just as is the case when a keeper is in its appropriate place, each of its ends being in contact with one of the poles of the same magnet, the influence of these has a concurrent effect in producing an opposite polarity at the extremities of the keeper.

866. Respecting the efficacy of this machine, the following is the substance of a statement in a letter from my sagacious and much esteemed friend and pupil, Dr. W. F. Channing. The unmitigated shocks from this machine are insupportable. When the wires which break the shocks are removed, the current becomes sufficiently uniform to be competent for electrolysis or imparting magnetism to iron included in a long helix of fine wire comprised in the circuit of the helices of the machine. When sent through a circuit of a mile, the current from this machine, was found abundantly competent to work the telegraph of Professor Morse.

Of Ferro-dynamic Induction.

867. I venture here to use an epithet for which I have no authority, so far as respects the employment of the Latin word for iron to designate the property of a mass of this metal to heighten the inductive influence of a coil by which it is magnetized, whenever the primary current is set in motion, and de-magnetized when this current is arrested.

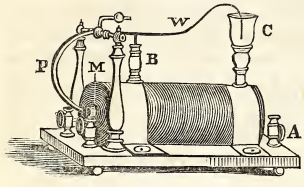
Of Callan's Faradian Apparatus, and Page's Callan and Faradian Electrotome.

868. Instructed by the observations of Faraday above alluded to, Professor Callan constructed a very powerful apparatus, by surrounding an iron cylinder with two coils of covered wire, one within the other, the inner coil being coarse and short, the outer one long and slender. When the inner coil was made to form the circuit of a voltaic battery, the other was found to give severe shocks or brilliant sparks, at the moment of interrupting the circuit.

869. Dr. Charles Page has contrived several instruments upon the same Faradian principle. One of these is extremely interesting and ingenious, as it is so constructed as that the magnetic attraction of the included iron, arising from the influence of the circuit, attracts a lever from the position in which it forms a necessary portion of the circuit. The circuit is thus broken, but as the lever falls into its previous position, the circuit is renewed. Each time that the removal of the lever takes place, a shock is received by a person duly communicating with the terminations of the finer wire; and

a brilliant spark appears as often as the lever quits the surface of the mercury.

Fig. 91.



870. The apparatus alluded to, is represented by the adjoining figure 91. A coil of coarse covered copper wire is wound about a bundle of straight coarse iron wires like knitting needles. The helix thus constituted, is surrounded by a helix of fine covered copper wire of at least one thousand feet, of which the ends are soldered to copper set screws inserted into the base board on the right. These set screws are for attaching severally one end of each of two wires, having a handle at the free end. One of the ends of the inner coil is attached to the set screw A, on the right, while the other end of this coil is soldered to a brass band which secures the coil and supports the brass cup B, holding mercury. The cup C similarly occupied, is connected with another set screw corresponding to A, in size and situation. The wire W, which plays on a horizontal axis by means of a spur and its right hand termination, establishes a conducting communication between the cups of mercury B and C, when it is kept down by its own unresisted weight. It carries, however, a piece of iron at the left extremity, within half an inch of the bundle of coarse wires. As soon as the set screws on the right, which communicate with the coarse coil, are made to receive the electrodes of a galvanic battery, the bundle of wire acquires an intense magnetic power, and attracting the iron attached to the wire beam W, lifts the right end out of the mercury in the cup C. This breaks the circuit, to which the magnetic attraction of the coil is due, and the weight of the wire beam no longer counteracted, causes it to fall back to its primitive situation. The magnetism is thus renewed, and the circuit is again interrupted, by the lifting of the end of the wire beam above the surfaces of the mercury in C. These alternations are accomplished with surprising rapidity, a brilliant spark being given as often as the contact with the mercury is broken. Meanwhile a person grasping the handles attached to the ends of the smaller coil, will receive a shock at every breach of the circuit, through the coarser coil. The shocks thus experienced with an apparatus of a moderate strength and size, will be found very severe.

871. Of the shocks resulting from the inductive power of one current upon another, an account has been given. In that case, it seemed as if the effect of a larger coil upon a smaller one, is to cause a degree of electro-polarity commensurate with the weight and length of the inducing mass, but that in the discharge of this polarity, the intensity was inversely as the sectional area of the wire forming the coil.

872. But in the secondary current produced in Callan's apparatus, or Page's modification of it, which I have been describing, we have added to the reaction of all the electro-polarity of the coil, an additional force from that of the magnetic polarity of the iron. The iron in the electrotome undergoes the same magnetic change as that in the armature of the magneto-electric machine, although from a different cause. In the one case it *produces* a current, in the other it merely *promotes* a current, which would exist independently of its aid.

Decomposition aided by the Influence of the Resiliating Current of an Electrotome.

873. M. De la Rive has devised an apparatus which he terms "Condensature Voltaique." It comprises a small bar of iron, on which is closely wound thick copper wire, covered with silk. Through this wire the current of a single voltaic pair is made to circulate, while by means of a little electro-magnetic apparatus acting like Page's electrotome above described, the circuit of the current is broken and reversed. An apparatus for the decomposition of water being included in the circuit, it is found that the electrolytic effect of the voltaic pair employed is nearly doubled; while a bright light is afforded by interposed charcoal points. The voltaic condensor succeeds well only with a battery on which two electrolytes are used, as in those of Daniell, or Grove. For its success it is necessary that two chemical actions be going on at once within the voltaic pair employed with it. The wire wound around the bar should also be large in diameter, and of moderate length. The action of the apparatus is referred, by its inventor, to the depolarization of the platinum electrodes in the decomposing cell. Since its introduction into the circuit, however, produces precisely the same effect as would result from an addition to the number of pairs, a part at least of its efficacy must be referred to the efficiency of the iron as a reservoir of the polarity of which the resiliating discharge (775) takes place, with a velocity greater than that with which it is accumulated.

Page's Apparatus for Regulating the Energy of the Resiliating Shocks of a Magneto-Electrotomic Apparatus.

874. The great power of iron in increasing the capacity of a coil, upon Callan's construction, to give shocks, is beautifully illustrated by an apparatus made by Davies, under the direction of Doctor Page. Agreeably to the construction of this apparatus, two different coils, one of fine, the other of coarse wire of Callan's apparatus are separable. Figure 92, represents the instrument in question, as when the parts are duly associated. In figure 93, it appears as when the coils have been taken apart. The external helix, *a*, is formed of fine covered copper wire, not being less than one thousand feet in length. The ends of this coil are soldered severally to the set screws C, D. The inner coil consists of not less than three strands of coarse copper wire. The ends of these strands, which terminate in the same direction, are soldered all to the set screw A, on the base board. The other ends of the three strands are soldered to the serrated

Fig. 92.

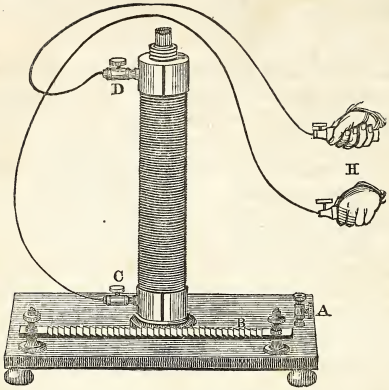
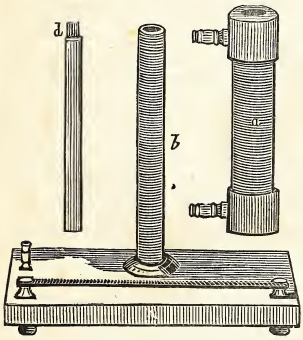


Fig. 93.



steel bar B: when these coils are situated one within the other, as in figure 92, on subjecting the inner coils to a galvanic current by attaching one of the electrodes to the set screw, the other electrode being in contact with B, on drawing the end of the wire, forming the electrode, over the teeth of the serrated bar, a brilliant spark will be seen as the wire leaps from one asperity to the other. If, during this process, wires with metallic handles be attached severally at C and D, a person holding the handles will receive for every spark a perceptible shock. The addition of a single wire like a knitting needle will increase the shock sensibly, and by the further addition of such wires the shock will be greatly increased, so that if the galvanic battery employed has only a square foot of zinc surface, the sensation becomes such as few are willing to bear. A rod of iron is not quite so efficacious as the bundle of wires of equal size. The inductive influence of the wires is not intercepted by their inclusion in a glass tube, but is much impaired by inclusion in a brass tube, in consequence of its diffusive power lowering the intensity. This is consistent with the experiments of Henry, with flat coils (799). The brass tube, like the metallic sheets, interposes a closed and perfectly conducting circuit.*

* A more convenient form for the application of these shocks as a remedial agent is displayed by figure 115, by which the mode of operating is fully illustrated. The circuit with the battery is established by means of the wire reaching from the set

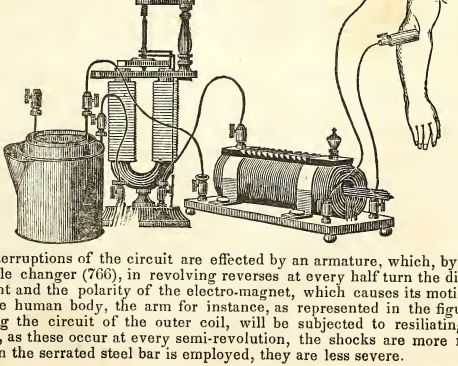
Of Thermo-Electricity.

875. When the needle of a galvanometer is deflected by the proximity of any body or set of bodies, of which different portions are of different temperatures, the phenomenon is ascribed to a thermo-electric current in contradistinction to those produced by galvanic apparatus. These have been distinguished by some electricians as hydro-electric currents, as in the necessity of water to their existence, they differ most pointedly from the currents above mentioned, which owe their activity to dry heat.

876. A thermo-electric current resembles a galvanic current of great quantity, but as to intensity extremely feeble. Other things being equal, a thermo-electric current flows from the hotter to the cooler portion of the mass. For the advantageous exhibition of this property, the bodies employed should have a great length in proportion to their other dimensions, as in wires or prisms. If the prisms of two heterogeneous metals have a conducting communication with each other between an extremity of each, while the other ends are in contact, or united by a slight soldering, on heating the ends associated as last

screw on the base board to one on the battery, while from the other on the battery, a wire proceeds through the coil of an electro-magnet to a set screw connected with the coarse inner coil of the electrotome.

Fig. 94.



The interruptions of the circuit are effected by an armature, which, by means of Page's pole changer (766), in revolving reverses at every half turn the direction of the current and the polarity of the electro-magnet, which causes its motion. Any part of the human body, the arm for instance, as represented in the figure, when completing the circuit of the outer coil, will be subjected to resiliating shocks. Although, as these occur at every semi-revolution, the shocks are more numerous than when the serrated steel bar is employed, they are less severe.

mentioned, a current ensues from one metal to the other, through the juncture. The current flows always the same way, when the same metals are employed. The metal from which the current flows is said to be positive to the other. It should be called thermo-positive, and those which are relatively negative thermo-negative.

877. The reaction in this respect is of course consistent with that established in respect to metals employed in analogous galvanic processes. As the current in a galvanic triad is stronger in proportion as there is greater discordancy in the relation of the metals employed, so in thermometric apparatus there seems to be a series, in which each metal is positive as respects all that follow, and negative, as respects all that precede it. Heretofore bismuth was deemed the most thermo-positive, antimony the most thermo-negative of the metals, and hence, until lately, the most efficient thermo-electric batteries were made of bismuth and antimony. Recently, however, German silver has been found nearly as thermo-positive as bismuth, and is preferable from not being so exceedingly fusible. This fusibility limited the deflection of a needle, subjected to a current produced with a pile of bismuth and antimony, to 82°; while German silver with antimony caused a deflection of 88°. German silver, however, while producing with antimony a deflection of 88°, produced under like circumstances a deflection of 85° with silver, brass, iron, palladium, copper or cadmium; being positive to all of them. With zinc it produced a deviation of 84°.

878. It has been shown by Nobili, that cylinders of clay partially baked, are capable of yielding thermo-electric currents.

879. As in the case of a galvanic circuit, a diversity, in the surfaces of the same metal or in the liquids to which it may be exposed, will enable it to act as two metals, and to give a current from one to the other; even partially twisting a wire, will cause the twisted portion to act as the negative metal, heat being applied at a certain distance from the twist.

880. In all cases where thermo-electric currents are concerned, no less than where those of galvanism prevail, the circuit must be completed in order to have a current.

881. It does not appear that there is any connexion between the thermo-electric, and galvano-electric relation of

metals, and those which exist between them as respects weight, specific gravity or conduction either of heat, or electricity. As heretofore combinations of antimony and bismuth were found most efficacious, the one being pre-eminently positive, the other pre-eminently negative, the idea arose that these metals might be indebted for this superiority to their eminently crystalline structure; but it has been found that German silver, with antimony, is more powerfully positive than bismuth is with that metal, although German silver is a malleable metal, of which the structure is not remarkably crystalline.

882. For the following table we are indebted to Cumming, one of the most distinguished among the cultivators of this branch of science.

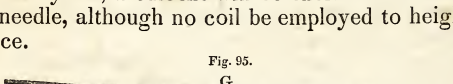
Thermo-electric series.	Hydro-electric series.	Series of conductors, of Electricity.	of Heat.
Galena	Potassium	Silver	Silver
Bismuth	Barium	Copper	Gold
German silver	Zinc	Lead	Tin
Mercury, Nickel	Cadmium	Gold, Brass, Zinc	Copper
Platinum	Tin	Tin	Platinum
Palladium	Iron	Platinum	Iron
Cobalt, Manganese	Bismuth	Palladium	Lead
Tin	Antimony	Iron	
Lead	Lead		
Brass	Copper		
Rhodium	Silver		
Gold	Palladium		
Copper	Tellurium		
Silver	Gold		
Zinc	Charcoal		
Cadmium	Platinum		
Charcoal, Plumbago	Iridium		
Antimony	Rhodium		

883. If to a platina wire which has been twisted about the middle, a flame be applied at some distance on one side of the twist, the ends of the wire being previously made to communicate through a galvanometer, the needle will indicate that a current flows from the heated part towards the twist. This is ascribed to the twisted part being cooler than the untwisted portion of the wire equidistant from the flame in consequence of a diminution of conducting power caused by the derangement of the metallic fibres during the torsion.

884. The needle will in like manner be affected, if a wire similarly communicating with a galvanometrical coil, be divided in the middle, then each end twisted, and one of the twisted ends, after being made red hot, brought into contact with the other. Similar results though feebler, may be obtained by means of copper and silver wire. That these effects do not depend on chemical reaction with the atmospheric oxygen, has been ascertained by their succeeding under pure oil.

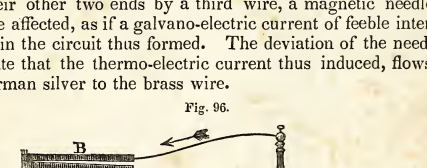
885. If one-half of a ring or rectangle, consisting either of bismuth or antimony, be heated, while the other half is kept cool by ice, a current will be excited sufficient to affect a needle, although no coil be employed to heighten its influence.

Fig. 95.



886. Let one end of a wire of German silver G, be brazed to one end of a brass wire B, on heating the juncture and making a communication between their other two ends by a third wire, a magnetic needle duly applied will be affected, as if a galvano-electric current of feeble intensity were circulating in the circuit thus formed. The deviation of the needle is such as to indicate that the thermo-electric current thus induced, flows from the wire of German silver to the brass wire.

Fig. 96.



887. In the preceding figure, at B a bar of bismuth is represented, at A a bar of antimony, exactly alike as to dimensions. Each is represented as communicating, at one end, with one of the terminations of the wire of a galvanometer. Their other ends are, while touching, exposed to the flame of a lamp. Under these circumstances the needle of the galvanometer will be deflected. Of course the arrows indicate the current to take place, from the thermo-positive metal, to that which is comparatively thermo-negative.

888. Figure 97, represents a series of eleven pairs of German silver and brass wire, arranged in two rows, and soldered as above described in voltaic order. It is sufficient to heat or cool the junctures on either side to produce a current competent to deflect the needle of a galvanoscope, with

Fig. 97.

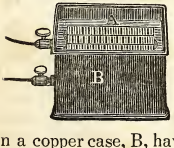
which it is made to communicate as represented by figure 96. Even the heat of the hand is sufficient to cause the needle exposed to the consequent current to deviate to a perceptible extent.

Construction of a Thermo-electric Pile of Bismuth and Antimony, illustrated by an Engraving.

889. Let any number of bars of bismuth and antimony, exactly similar in all their dimensions, be bundled together, paper being interposed between their lateral surfaces, so as to avoid metallic contact. Let the neighbouring ends of the heterogeneous bars thus associated be alternately soldered, and alternately left free, so that any bar will have only one soldering at each end, and not be soldered at more than one end to any one bar. The order in which the bars must be united is exemplified in figure 97. The bars thus connected, will form one continuous metallic conductor, consisting alternately of bismuth and antimony, so that on taking the whole into a galvanic circuit, all lateral discharge being prevented by the paper, the current entering by a bar of bismuth, would proceed through a bar of antimony, then through a bar of bismuth, and so on coming out finally through a bar of antimony. The metals are in fact alternated like those of the couronne des tasses, excepting that the fluid, instead of being alternately conducted by metal, alternately transmitted convectively through an interposed liquid, is conveyed from bar to bar, wholly through the alternate metallic junctures.

890. The metals thus associated, exercise, when their alternate solderings are at different temperatures, an electro-motive power due altogether to their contact; so that the contact theory of Volta, however incompetent to account for the powers of his pile, seems to be somewhat applicable in the the case of the thermo-electric series. It is not pretended, that in the case of the apparatus last mentioned, any chemical combination takes place, unless the successive passage of heat from particle to particle be considered as warranting such an idea.

Fig. 98.



891. By figure 98, a thermo-electric battery is represented, consisting of sixty-three pairs of bars of bismuth and antimony, each three inches in length, three-fourths of an inch in breadth, and one-fourth of an inch in thickness, of course the bars are soldered to each other alternately, as above described, so as to be arranged in a series in voltaic order. They are insulated and secured by plaster of Paris, in a copper case, B, having above them, a space for receiving ice, and below another so situated as to be exposed to an appropriate cast iron plate, previously heated to redness.

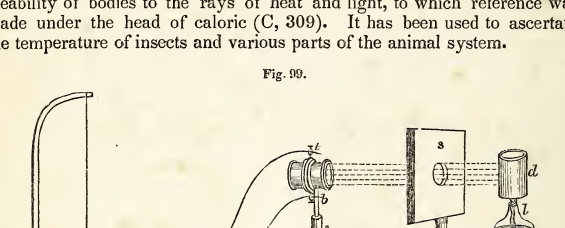
892. Two set screws for attaching wires are represented externally, each of which is made to communicate with one pole of the battery. The energy of the current is in proportion to the difference of temperature, created in

those solderings of the bars, which are in the different surfaces of the bundle which they form collectively, by the application of heat at one surface, and cold at the other surface. Of course the greatest power results from applying ice or a cold mixture to the solderings at one of the surfaces, and at the other as much heat as bismuth will bear from a hot iron without fusion. A series thus constructed, caused the electro-magnet of Riche's apparatus to revolve rapidly. A serrated bar is attached to the front of the case, and is connected with one of the poles of the pile. When a wire, of which one end is affixed to a set screw soldered to the other pole, had the free end drawn over the teeth of the serrated bar, sparks were produced.

Of Melloni's Thermo-multiplier.

893. By means of a thermo-electric series analogous to that illustrated by the preceding figure, associated with an extremely sensitive galvanometer, Melloni contrived a thermoscopic apparatus, more capable of detecting minute differences of temperature than any before known. It proved the means of making those interesting discoveries, of the difference in the permeability of bodies to the rays of heat and light, to which reference was made under the head of caloric (C, 309). It has been used to ascertain the temperature of insects and various parts of the animal system.

Fig. 99.



894. The series employed by Melloni, consisted of fifty pairs, about an inch and a fifth in length, and the whole forming a bundle of little over an inch in diameter. It was included in a cylindrical brass case, between which and the bars, no metallic contact was permitted. Wires proceeding from the extremities of the series were made to communicate with set screws *b*, *t*, insulated from the brass case by ivory.

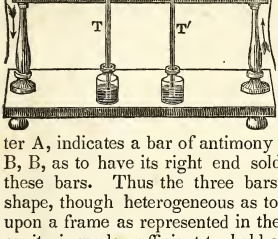
895. The mode in which this thermoscopic apparatus was employed, may be understood from the preceding figure. The heat of the copper cylinder *d*, received from the lamp *l*, reaches one side of the thermo-electric series through a hole in the screen *s*. The other not being exposed to the influence of any hot body. Under these circumstances a thermo-electric current is produced through the coil of the galvanometer, which by the attachment of its ends to the set screws *b*, *t*, is made to complete the circuit between the poles of the thermo-electric series.

896. It is inferred that the difference of temperature, created by the radiant heat reaching the surface of the series exposed thereto, will be as the quantity of electricity, and that as the deflections of the galvanometer measure the

electricity, they must also be an index of the degree of heat applied at the appropriate surface of the thermo-electric series. Melloni alleges, that this correspondence between the heat applied, and the deflections, has been ascertained to exist.*

The Converse of the Thermo-electric Process.

Fig. 100.



897. The object of figure 100, is to represent a thermo-electric apparatus, in which the phenomena are the inverse of those produced by the thermo-electric batteries, described in the preceding pages. In those a current of electricity is the consequence of a diversity of temperature; in the apparatus in question a diversity of temperature is the consequence of an electric current. The letter A, indicates a bar of antimony so situated between two bars of bismuth B, B, as to have its right end soldered to one, the left end to the other of these bars. Thus the three bars, form one metallic prism, uniform as to shape, though heterogeneous as to the materials, which rests horizontally upon a frame as represented in the figure. At each soldering a little concavity is made sufficient to hold a small quantity of water, and to receive the bulbs of the two air thermometers F and T. The water serves to facilitate the conduction of heat from the metal to the glass bulbs. The prism formed as described, of bismuth and antimony, being made the channel of a galvanic current, in the direction indicated by the arrows, from B through A to B, at the soldering of A to B, cold is produced and made evident by the thermometer T. Meanwhile on inspecting the other thermometer, it will be seen that heat is produced at the other soldering. By reversing the direction of the current, the effect on the thermometer will be reversed.

898. The extent of the elevation above the previous temperature is greater than the depression. This is ascribed to a small degree of heat, which the electric current causes, and which of course adds to the heat on one side, and lessens the cold on the other.

On Terrestrial Magnetism.

899. The thermo-electric branch of science has a pre-eminent importance from the light which it has thrown

* The following are the dimensions of the galvanometer or thermo-multiplier of Melloni and Nobili, associated with the thermoscopic apparatus as stated by Bequerel.

The wire is of copper doubly wound with silk, and of about three-hundredths of an inch in diameter. It makes 150 circumvolutions around a frame of about two inches square, and one-fourth of an inch in height. The needles are a little short of two inches in length.

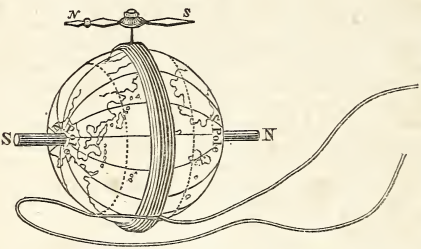
It will be perceived that there are two needles associated so as to form what is called an astatic needle. They are suspended by a single cocoon filament. In the apparatus as described by Bequerel, the cocoon is attached at the upper extremity to a swivel, as in the torsion electrometer of Coulomb, (E, 136,) and the frame may be made to rotate by means of a toothed wheel and pinion so as to adjust the needle to zero, of the graduated arch of ninety degrees, by which the deflections are measured. There is also a contrivance for lowering the needles so as to rest on the frame on which the wire is wound. When thus situated if it be desired to transport the instrument from one place to another, the needles are bound fast to the surface of the frame by a silk ribbon. The apparatus is included in a bell glass to protect it from being agitated by blasts of air, or soiled by dust.

on the nature and causes of the all-important polarity of the earth. This is now ascribed to the successive influence of the solar rays upon the temperature of the earth, causing a perpetual thermo-electric current from east to west.

900. It is by the reaction of its poles with this terrestrial thermo-electric current, which flows parallel to the equator, that the compass needle is made to arrange itself at right angles to that current, and thus to assume a direction nearly coincident with that of the meridian.

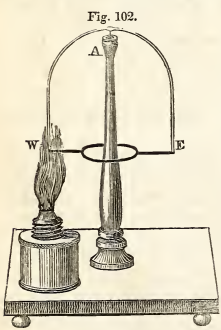
901. In the following figure, a coil of covered copper wire affords the means of causing an electrical current to circulate about a globe repre-

Fig. 101.



senting the earth. A magnetic needle is represented in the position, in which it would arrange itself by reaction with the current in the coil.

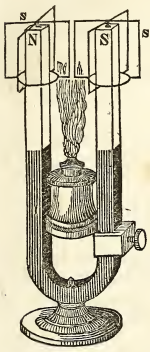
Fig. 102.



902. The apparatus represented by figure 101, serves to illustrate the reaction, with the magnetism of the earth, of a thermo-electric current, produced within an arch of brass wire soldered at its two ends to a ring of German silver. The arch is poised upon a pivot at the top of the pillar at A, which the ring encircles. The lamp, W, being situated as in the figure, the apparatus must be so placed, that a line passing through the centre of the flame to that of the pillar, will be directed from west to east. Then, when the flame is applied to the juncture of the arched wire with the ring, a current will flow from the juncture, and of course from west to east through the arch. As this current will conflict with that of the earth, it will cause the wire to arrange itself, so as that this discordance may be avoided. But a semi-revolution bringing the other juncture of the arch and ring into the flame, a current through the arch from west to east is again induced, producing another semi-revolution. Of course this process will be repeated as long as the flame is applied.

903. Another illustration of the efficacy of thermo-electric currents, is afforded by their displaying an analogous reaction with a permanent steel magnet to that which has been shown to exist between such a magnet and the currents created by galvanism, in the experiment designated as that of Ampère's rotating battery (757).

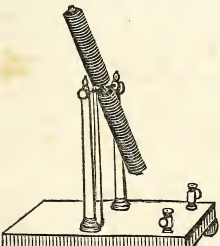
Fig. 103.



904. The frames of wire in the rectangular form, supported on the jaws of the permanent steel U magnet, as represented in the adjoining figure, may consist of silver in rings and platinum rectangles, or the rectangles may be of silver, and the rings of German silver. When the junctures of these frames are subjected to a flame as represented in the engraving, electric currents are made to flow in each from the heated juncture, through the silver wire, to the other juncture. The currents, thus incited, conflicting with the polar influence of the magnet, endeavour to arrange themselves so as to escape from conflict. But the only motion which the suspension will permit, is that of rotation, which, by bringing a juncture into the flame at every quarter revolution, causes the effort for a change of position to be repeated as often. Hence the frames revolve as long as the flame is applied.

Electro-magnets revolving under the Influence of Terrestrial Thermo-electric Currents.

Fig. 104.



905. It has been shown, that an electro-magnet, situated on an axis, and subjected to the polar influence of another magnet, will strive to arrange itself so as to bring opposite poles into proximity; but that if the current to which it is indebted for its magnetism be, from the construction, liable to be reversed by a pole changer at every semi-revolution, a rotary motion will ensue. Two instruments have been constructed, in which terrestrial polarity is made to take the place of an artificial magnet, or an electrical current. One of these revolves in a horizontal plane, the other in a vertical plane; the latter having the same relation to the dipping needle that the former has to the compass needle. The instrument which revolves vertically, is represented by figure 104.

Of the Electro-magnetic Telegraph.

906. Though the attempts which have been made to employ electro-magnetism, as a moving power, have hitherto failed, yet another important application of this agent has been made within a few years, in our own country, by

Prof. Morse, and in England by Messrs. Barrit and Cook, and Prof. Wheatstone. With the telegraph of Morse, which has been the medium of communication between the cities of Baltimore and Washington, the public has become familiar. The apparatus thus employed, is far superior in simplicity to any contrivance elsewhere put in operation, of which any knowledge has reached this country. A description of his instrument, as now in operation within the Capitol at Washington, is all that I deem it expedient to introduce.

907. Upon a base board of wood, a U shaped bar of soft iron, wound with covered copper wire, is firmly attached in a vertical position. One of the terminal wires of the electro-magnet thus formed, communicates with the distant station by means of a wire, the other by means of the ground. A short distance above the electro-magnet, a bar or keeper of soft iron is attached at right angles to a lever. One extremity of this lever carries a steel point or tooth projecting downward, while through the other extremity is a pivot supported by two stanchions behind the electro-magnet. A spring is attached to the upper surface of the lever tending to raise this, and with it the keeper, from the poles of the electro-magnet beneath. When the circuit is completed with the voltaic battery at the distant station, the electro-magnet being charged, and suddenly attracting the keeper, causes both it and the lever to descend. Upon the rupture of the circuit, attraction between the magnet and keeper ceasing, the spring causes the lever to rise again, and thus, by repeated completions and interruptions of the circuit, the lever may be made to play up and down, working upon the pivot as a fulcrum. Immediately beneath the steel point a cylinder of wood, covered with soft paper, is made to rotate upon an axis uniformly by means of clock work. When, by the completion of the circuit, the steel point is made to descend, it presses upon the soft paper of the revolving cylinder only so long as the circuit remains unbroken. As the cylinder revolves, a dot or a line of greater or less length is described upon the paper, and an arbitrary combination of such dots and lines constitutes the alphabet. Thus every letter may be written upon the paper at one extremity of a telegraphic line of any length, by successive completions and interruptions of the circuit at the other.

908. As the velocity with which the electric current traverses a metallic wire has been found by Mr. Wheatstone to be about 288,000 miles in a second, it is obvious that no perceptible interval of time will elapse in the transmission of intelligence in this way, between any two points upon the earth's surface.

909. Various modes of establishing the wires between two stations have been devised. It was at first proposed to enclose two insulated wires within an iron pipe, buried beneath the surface of the earth; but this method is objectionable on the ground of expense, and liability to derangement. As above stated, Prof. Morse employs the earth itself for one-half of the circuit, and a wire, supported upon poles at some distance above the ground, as the other.