THE

MODERN SEVEN WONDERS OF THE WORLD

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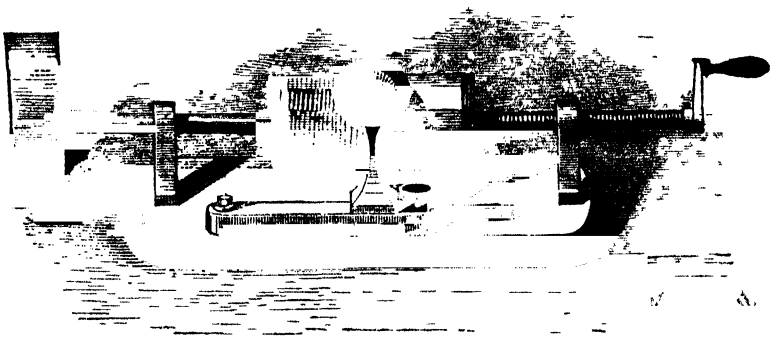
By CHARLES KENT

"The fairy tales of science and the long result of time."—LORD TENNYSON

"The measure of impossibilities is lost in the present age."—CHARLES READE



EDISON'S FIRST PHONOGRAPH

WITH NUMEROUS ILLUSTRATIONS

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TO

PROFESSOR JOHN TYNDALL,

THIS ATTEMPT TO POPULARISE THE TRUTHS HIS

PROFOUND RESEARCHES HAVE HELPED TO

ILLUSTRATE AND ADVANCE

Is Inscribed

WITH SENTIMENTS OF THE SINCERESTRESPECT

AND ADMIRATION.

ATHENÆUM CLUB,
July, 1889.

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THE

MODERN SEVEN WONDERS OF THE WORLD.

I.—THE STEAM ENGINE.

"An earthquake with thunder and lightning going up express to London.
—CHARLES DICKENS.

MORE than two thousand years ago a Greek philosopher constructed a toy which—remembering the marvel that has since grown out of it—may be compared without the smallest exaggeration to the brass pot, containing the Genie, dragged up from the depths of the sea by the Arabian fisherman. According to the Sultana Scheherazade, the pot in question was a worthless-looking receptacle enough, concealing no treasure, and apparently quite empty. From it, however, emerged a Vapour which, after spreading far and wide over earth and ocean, resolved itself into a Power that became thenceforth its emancipator's most obedient slave and benefactor.

B

Distinctly akin to this was the scientific toy (Fig. 1) above referred to, which was fabricated during the third century before the coming of our Lord. It consisted of a hollow sphere of metal (A) lightly held

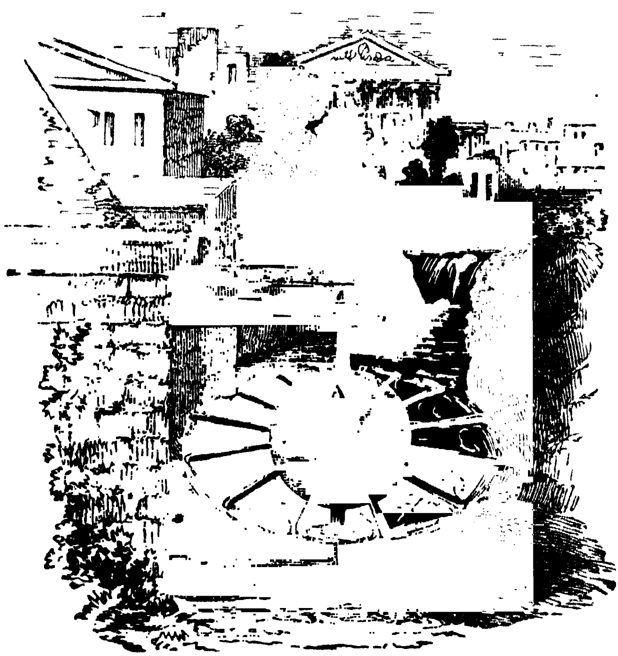

Fig. 1.—Hero's Æolipile.

between pivots (B and C), above and below, so as to be capable of twirling easily betwixt them upon a vertical axis. A number of small tubes having been screwed into the circumference of this globe so that they radiated from it horizontally, like the spokes of a wheel—each tube having its extremity bent to a right angle, and perforated with a minute orifice—water was introduced into the orb and a fire kindled underneath. Thereupon, so soon as the spherical vessel and its contents had become sufficiently heated, the steam generated within, escaping in a violent jet through each bent nozzle, by its reaction caused the globe immediately in its recoil to revolve, its rotation thus continuing until the whole of the water inside it had whizzed away in vapour. Such in a few words was the pretty bauble of the Æolipile or Ball of Æolus, in which its inventor contrived not only to employ steam for the first time as a motive power, but so to apply it, even sportively, as to produce at the very outset, what was virtually the crowning achievement of the perfecter of the Steam Engine twenty centuries afterwards—the revolutionary movement! Does any one ask who was the Hero of Science whose genius wrought out this wonderful plaything which, in a remote age, was little by little to be developed into a marvellous and complicated piece of mechanism? Let it be said at once that his name has been uttered in the very putting of the enquiry, for it was Hero of Alexandria. Little dreaming of what was to come of it so long afterwards, he took occasion to describe the toy in his treatise on Pneumatics. And, toy though it was, it was certainly an achievement: for, as distinctly as the acorn is the seed of the oak, the Æolipile was the germ of the Steam-Engine. Vitruvius, writing in the reign of Augustus Cæsar, refers to it as a contrivance then perfectly well known, just as Professor Huxley might, now in the reign of Victoria, make some casual allusion, say in a foot-note, to the Zoetrope or Wheel of Life.

Eighteen centuries had actually run out before anyone had dreamt of turning to account Hero's discovery of the impulsive force of steam as exemplified by his ingenious bagatelle. Then, however, in 1543, a Spanish Sea-Captain, one Blasco de Garay, astonished the Emperor Charles V. by proposing to propel a vessel unprovided with either oars or sails by means of some mysterious machinery the nature of which he declined to explain. Further than this, on the 17th of June in the year just named, he actually made good his offer within view of a multitude of spectators in the port of Barcelona. There, on board *The Trinity*, 200 tons burthen, having previously fastened upon either side of her a huge water-wheel with, between the two, amidships, a ponderous boiler and some other (hidden) mechanism, he succeeded in navigating the vessel at a rapid pace at his own good will and pleasure. Although the experiment was so far undoubtedly a triumph that De Garay at once obtained promotion, besides having his expenses paid, as well as receiving a handsome pecuniary recompense, nothing more ever came of his extraordinary feat, the secret of which, it has been reasonably conjectured, was no more than the adaptation to marine purposes of the contrivance of Hero of Alexandria. Certain it is that in 1567, Philibert de l'Orme, as though the notion of the Æolipile had, not long before, been in some marked way recalled to his remembrance, threw out the suggestion incidentally in his treatise on Architecture, that its discharge perpendicularly through a single pipe might be advantageously employed in hastening the ascent of smoke up a chimney. A generation had just run out after this, when, at the very dawn of the following century, a Neapolitan mathematician of some distinction, Giambattista della Porta, famous even to this day as the inventor of the Camera Obscura, not only made clear, in a work published by him in 1601, how much steam might be raised from a given quantity of water, but, by demonstrating yet further how its energy might be employed in lifting that element above its level, showed in an unmistakable manner his sense of the value of the truth revealed by the seemingly frivolous device of the Æolipile.

Fourteen years later Solomon de Caus, an engineer originally engaged in the service of Louis XIII. of France, but afterwards in that of the Elector Palatine who married the daughter of James I. of England, made plain enough by an apparatus (Fig. 2) set up by him in 1615 that very much indeed might yet be accomplished with the aid of steam-power. Instead of allowing the vapour to blow itself off, as in the Ball of Æolus, he so denied it escape from the vessel (*a*) in which it was generated, that the mere pressure of its accumulation forced the boiling water itself to ascend in a small jet

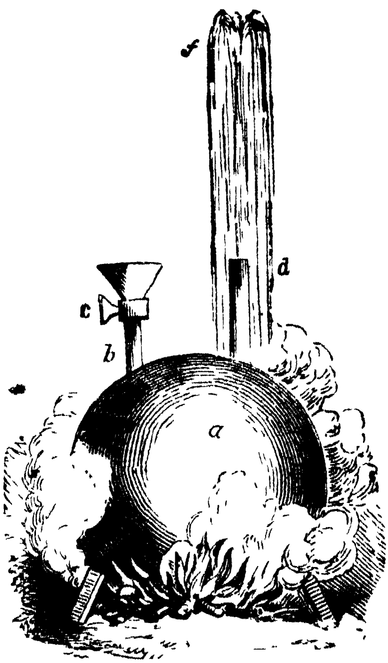

Fig. 2.—De Caus' Hot water Fountain.

or fountain (*f*) through an open tube (*d*) by twisting the turncock (*c*) in the neck of the funnel-headed pipe (*b*) through which the water had been introduced until the emptying of the boiler of its contents was signalised by a final whiff of steam. De Caus' contrivance therefore, like Hero's, was after all a mere plaything, neither it nor the Æolipile being self-renewing in arrangement, or, in other words, productive of anything like continuous action.

Yet another fourteen years having elapsed, an Italian experimentalist named Giovanni Branca of Loretto, contrived, in 1629, to set the machinery of a mill in motion by directing a jet of steam against the flattened vanes or paddles of a wheel which the blast of vapour thus caused rapidly to rotate. Cornelius van Drebbel, again, who died at London in 1634, and who, although nearly as much of a charlatan during the early part of the seventeenth century as Cagliostro was in the later part of the eighteenth, is entitled to honorable remembrance as the inventor of the Thermometer, intimated shortly before his demise his conviction as to the probability of steam being eventually utilised as a motive power.

Respectful allusion to it as a possibility was even made by no less distinguished a philosopher than Robert Boyle who, in 1660, was chiefly instrumental, in association with Sir Christopher Wren and Sir Isaac Newton, in establishing the Royal Society. It is remarkable that only three years had expired after that great learned body had been called into existence, when there was published in London a work, small in bulk but most important in its character, in which was described with the utmost possible distinctness the first rough outline of a mechanical arrangement not unworthy of being called a steam engine. Whoever may be curious to examine the treatise containing that memorable description will find it ready to hand in its printed form among the contents of the sixth volume of the Harleian Miscellany, while the original draft may be turned to in No. 2428 of the Harleian Manuscripts. Popularly known as "The Century of Inventions," it puts upon record one after another to the number of exactly a hundred, the scantlings, as the author quaintly dubs them, of such discoveries and contrivances of his own as, at the time of writing, he could call to mind having tried and perfected. Given to the world first in 1663, the book sets forth as the sixty-eighth of its Century of Inventions what it whimsically designates "A Fire Water Work"—being in fact beyond all question an account of the first veritable steam-engine ever constructed. By its agency, steam was, with continuous action and renewal, so applied as to raise water to a considerable height.

Edward Somerset, better known by his patrician title as Marquis of Worcester, was the author of this treatise, the sixty-eighth clause of which makes good his right to be regarded as in some sense the earliest or original inventor of the steam-engine. Embarked in the great Civil War as an ardent Royalist, he soon realized that his fortunes were completely wrecked by the triumph of the leaders of the Commonwealth. Seeking refuge

Fig 3.—The Marquis of Worcester in the Tower of London watching the lid of the iron pot lifted by steam

in Ireland, he was there imprisoned, but after a brief incarceration effected his escape to France. Returning thence into England as a secret agent of Charles II., he was recognised almost immediately upon his arrival in London and forthwith immured in the Tower. There he remained in close confinement down to the time of the Restoration. It was during the period when he lay in durance as a state prisoner in the Tower of London that the Marquis of Worcester hit, as it were by accident and as a surprise to himself, upon the most notable of all his discoveries.

Seated one day before the hearth of his cell while his frugal dinner was cooking there in an iron pot, he observed the lid all of a sudden forced up by the vapour. Musing upon this (Fig. 3) he at once bethought himself whether steam might not just possibly with some contrivance be applied as a motive power. So dexterously was it employed by him, indeed, when he came to put it to the test, that it was dealt with then in that purely tentative machine precisely as it is in the steam engines of nowadays, the vapour being generated in one vessel and utilised in another by being brought into play there with certain mechanical appliances. Whereas Hero's Æolipile, as already shown, was capable of merely emptying itself of its contents in the form of vapour, while De Caus' apparatus could do no more than discharge its boiling water under the pressure of the steam that water had generated, Lord Worcester's engine was, by its alternate action upon two vessels, enabled to force water up to a height of fully forty feet in a continuous fountain. Nothing more, besides this, was required, to keep the engine steadily going, than that an attendant in charge of two cocks should turn, now one, now the other—the pair of vessels containing the water being thereby emptied and refilled in rapid succession. As indicative that this earliest steam engine on record had already, in its inventor's time, passed beyond the theoretic stage, it will be sufficient to remark that a machine of the kind having been erected by the Marquis upon the bank of the Thames at Vauxhall, for a long while supplied with water the whole neighbourhood.

Twenty years after the publication of Worcester's "Century of Inventions," Sir Samuel Morland, otherwise noteworthy as the contriver of the Drum Capstan and the Plunger Pump, as well as of an Arithmetical Machine, and of the most sonorous of all Speaking Trumpets, demonstrated in a remarkable manner the power possessed by steam for raising water to a great elevation. Appointed Master of the Works to Charles II., in 1680, he had been despatched in the following year across the Channel, to carry into effect for Louis XIV., some grand projected waterworks in the royal pleasure-gardens at Versailles. While still engaged upon this enterprise he wrote in French a wonderfully interesting little treatise that has never yet been published, but the original manuscript of which is still preserved at the British Museum, as one of the Harleian collection. Extending to no more than thirty-eight pages it is written entirely upon vellum As its very title intimates it sets forth "The Principles of the New Force of Fire invented in 1682 by the Chevalier Morland, and presented in 1683 to his most Christian Majesty." It lays particular stress upon the fact that water having been converted into vapour by heat, that vapour, by reason of its being elastic or expansive, requires a space, as the writer calculates, about 2,000 times greater—or as closer investigation has since demonstrated exactly 1700 times greater—than that previously occupied by the element from which it is generated. Sooner than be confined by the strongest gun-metal, steam is capable, as he goes on to relate, of shattering to atoms a piece of ordnance. But duly regulated by science "these vapours," quoth Sir Samuel Morland, "bear their load peaceably (*like good horses*) and thus become of great use to mankind." Reading upon the vellum those three parenthetic words which, in translating them from the French original, I have here italicised, I seem to recognize the origin, a little more than two hundred years ago, of the habit engineers have since then dropped into, of measuring the force of steam roughly and in round numbers by horse-power. It was this Sir Samuel Morland, by the way, whom John Evelyn tells us in his Diary, that he visited on the 25th of October, 1695, when the old sage, then "entirely blind," was—within fourteen months of its close—tranquilly running out the last sands of his life at Hammersmith.

A French physician who in his time was Professor of Mathematics at Marbourg, Dr. Denis Papin of Blois, oddly famous to this day as the inventor of Papin's Digester—a contrivance for the extraction of gelatine from bones after the latter have been duly softened under a very high temperature—was the next, in chronological order, of those who prepared the way, by the daring novelty of their suggestions, for the gradual building up of the steam-engine. In an ever memorable work, published by him in 1695 at Cassel, he threw out the notion that, as water has the property of elasticity when converted into steam by heat and as afterwards it is capable of being so completely recondensed as to produce a vacuum, it would not be difficult, with the help of fire and water, to work machinery. Papin it was, in fact, who first conceived the idea of applying a motive power thus through the medium of a piston working in a cylinder.

As to the raising of the piston by steam, that he saw at once might easily be accomplished. What proved to be the most arduous part of the difficult task he had set himself, was the discovery of the best means for producing a vacuum. Let but a vacuum be obtained and the mere weight of the atmosphere, as he well knew, would instantly cause the piston to descend in obedience to the law of gravitation. True, no doubt, that the atmosphere is merely relatively ponderable. But, enveloping the globe as it does to the height of thirty miles, it has everywhere upon the earth's surface, by reason of that perpendicular height (and accumulated weight) of thirty miles, a pressure of fifteen pounds upon every square inch. Dr. Papin's first endeavour was to produce a vacuum with the aid of an air-pump worked by a water-wheel. His next, which was equally unsatisfactory, was to effect the same result with the help of gunpowder. Finally, as if in despair of attaining his object by any more rapid and effectual means, he so arranged matters that, after having driven the piston up with the force of steam, and secured it momentarily by a catch at the top of the cylinder, he ensured the condensation of the vapour by the primitive device of bodily removing the fire from under the boiler—having done which the catch was released, and the piston, weighed by the atmosphere, descended.

Entirely unconscious of the investigations which were thus being made in France by the Professor of

Mathematics at the University of Marbourg, there was living at that time in England a keen-witted natural philosopher, one Captain Thomas Savery, who, as it happened, was arriving, by a wholly different process, at precisely the same conclusion. How it was that the idea originally occurred to Captain Savery, as to the best means of recondensing steam by the sudden application of cold water to the vessel containing it, he is said to have often related with gusto both before and after writing his little treatise entitled "The Miner's Friend; or an Engine to raise Water by Fire, described by Thomas Savery, Gentleman." Having one afternoon at a tavern in London regaled himself with a flask of Florence, he had just tossed off the last measure from it, when, chucking the empty flask upon the fire, he called for a basin of water to wash his hands. Reading the account of this incident, it is impossible not to realise more fully than ever the truth of the old saying that there is, after all, nothing intrinsically trivial in the universe.

A small quantity of the liquor, the merest dregs, yet remaining in the flask, we are told, began to boil while Savery stood there idly upon the hearth waiting for the tavern servant to bring him the ewer for his ablutions. Hearing the bubbling of the wine, and seeing the steam issuing from the mouth of the flask, Captain Savery all at once bethought himself that he would try what might come of it if he were suddenly to plunge the flask mouth downwards in the cold water. Thrusting his right hand into his thick leather glove, so as to guard himself from the risk of burning, he plucked the flask off the live coals, and sousing it neck down in the basin of cold water, which had just been placed before him, saw to his amazement that the liquid forthwith rushed up into the flask and completely filled it—proof positive to him that a vacuum had been instantaneously created by the steam's re-condensation!

Realizing at once the importance of the fact thus revealed, he saw his way at a glance to its effective application. Instead of laboriously exhausting the cylinder of a pump with the ordinary piston and clack-valve sucker, suppose, thought he, I were to force the piston up with the elastic power of steam, and were then abruptly to condense the vapour by chilling the pump-barrel externally! In that contingency, as he perceived in a moment, the piston—having a vacuum beneath it, and perpendicularly for the distance of thirty miles above it the pressure of the atmosphere—would by necessity descend as swiftly as it had just before ascended! Having thoroughly thought out his plans, Savery on the 25th of July, 1698, secured his rights by a patent which has an especial interest of its own as being the first patent that was ever obtained for a steam-engine. Before another twelvemonth had run out he had the gratification, on the 14th of June, 1699, of exhibiting a working-model of his engine before the Royal Society, upon which occasion the experiment succeeded not only according to expectation, but to the avowed satisfaction of those present, as I find duly notified under that date in the Philosophical Transactions.

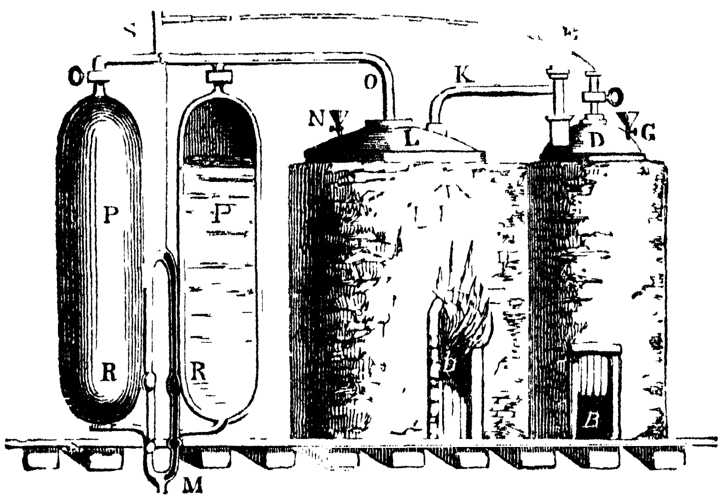

Fig 4.—Savery's Receivers and Boilers.

Like every other steam-engine since constructed, Savery's was put together (Fig. 4) in two divisions entirely distinct from each other. One generated the steam, the other brought the vapour into play as a motive power. What was especially remarkable about this earliest of all steam-engines was the circumstance that it was throughout of a duplex character. Besides having two furnaces (*b* and B) and two boilers (L and

D), a lesser and a greater, it had in direct communication with the latter two oval or egg-shaped copper steam-bulbs (P R), termed by Savery "receivers." Erected down in the shaft of any mine that required draining, at about forty feet from the bottom, it thence drew up the water (Fig. 5) through a common suction-pipe (T) alternately into each of these receivers upon the creation of a vacuum therein by the sudden condensation of the steam with which each had been previously filled. Thence, upon the re-admission of vapour from the boiler alternately into each receiver, the water was further driven upwards by the expansive power of the steam into a common force-pipe, S, which ascended the main-shaft side by side with the chimney, and from the orifice of which force-pipe, above the level of the pit's mouth, the water was discharged in a continuous stream, so long as the engine was maintained in action. A wonderfully ingenious contrivance for determining the level of the water in the boiler, which ought, as a rule, to be two-thirds full, was hit upon by Savery, an arrangement so perfectly effective that it is still employed. This was accomplished by the insertion of a couple of gauge-cocks in the top of the larger boiler, from the higher of which steam, from the lower of which water, ought to issue whenever the test was applied by the handles being turned. Whereas, if steam or if water issued simultaneously from both, the

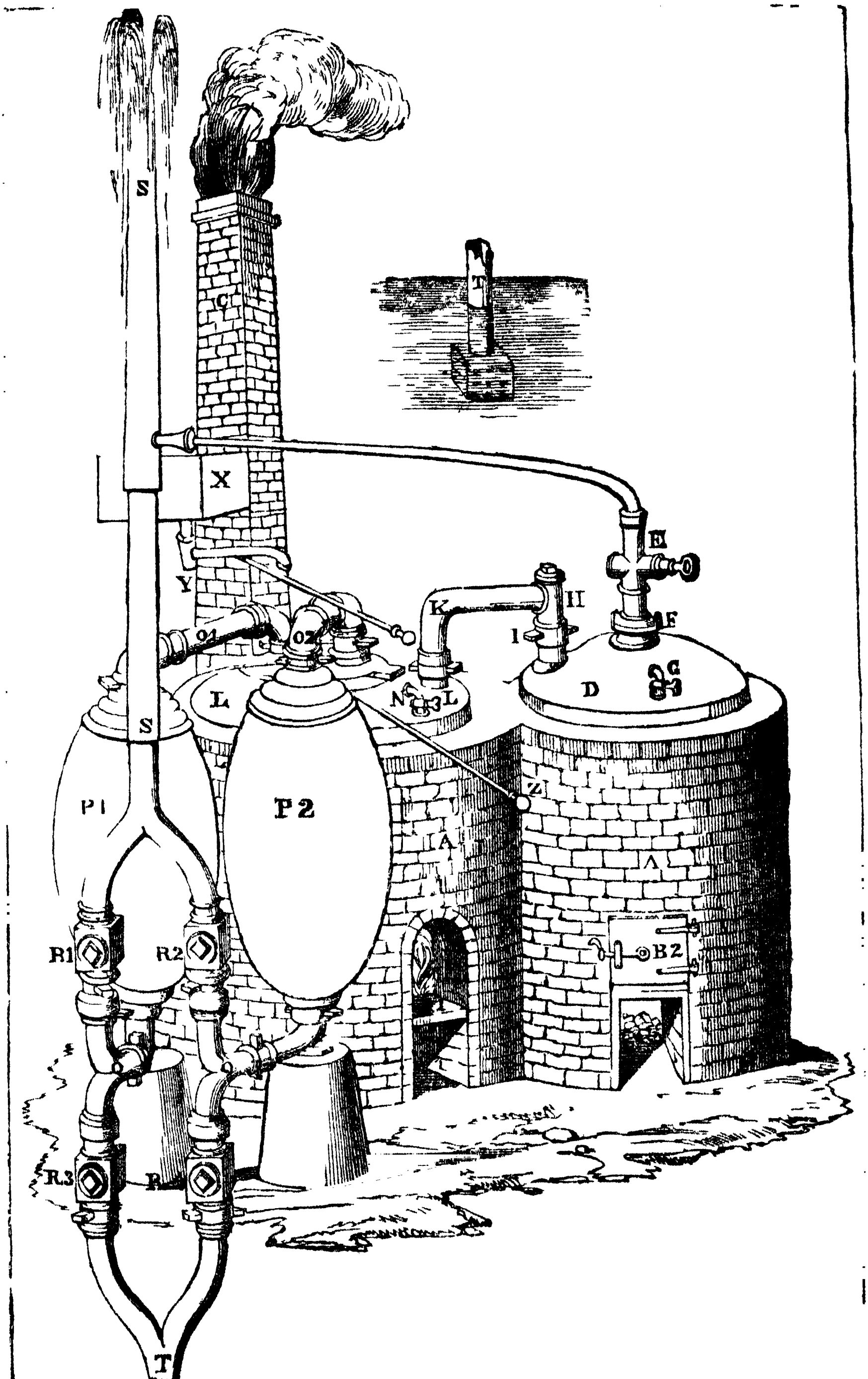

Fig. 5.—Captain Savery's Pumping Steam Engine

steam or the water, as the case might be, would be obviously in excess. Savery's engine, though introduced by him mainly as a means for raising water by fire, was employed at the beginning of the eighteenth century by Joshua Rigley, first at Manchester and afterwards in different parts of Lancashire, for the setting in motion of the machinery of the earlier cotton-mills. While, up in the metropolis, Peter Kier of St. Pancras adapted one of these machines to the twirling of all the lathes used in his large turnery establishment.

Although Savery's was beyond doubt the first real working steam-engine ever brought into operation, it was reserved for his immediate successor, so far to advance the machine towards its ulterior state of perfection, or at any rate completeness, that as it left the latter's hands, it remained without alteration or amendment of any very noticeable kind for nearly half a century. Allusion is here made, of course, to the reputed inventor of the Atmospheric Engine, Thomas Newcomen, first known as a blacksmith, afterwards as an ironmonger, and eventually as an engineer at Dartmouth in Devonshire. Intimately associated with him in his experimental investigations was a hardly less intelligent plumber and glazier of the same seaport, by name John Cawley. Patents for an atmospheric engine were taken out by the two of them in conjunction with Savery, first in 1705 and again in 1707, no machine having been constructed however until 1711, under either specification. Not until the March of 1712, in fact, was the earliest Newcomen engine successfully employed for the draining of water at Wolverhampton.

Papin, more than twenty years previously, had in 1690 conceived the idea, as will be remembered, of raising a piston in a cylinder by the expansive force of steam, and then, by suddenly creating a vacuum underneath it, by a rapid condensation of the vapour, enabling the piston to descend under atmospheric pressure. Curiously enough Savery, who was essentially the practical man as compared with Papin the theorist, although he discovered and actually brought into play the means of creating the vacuum which Papin had done little more than dream of, appears never to have thought of adapting to his engine, with all its perilous high pressure, the beautiful expedient of the Safety-Valve, first contrived by Dr. Papin as far back as 1681, for his Digester. Not, in fact, until Captain Savery was dead, was the safety-valve first applied, in 1717, to one of his pumping-engines by Dr. John Theophilus Desaguliers.

That marvellously simple and ingenious contrivance has since then been employed in steam-engines of every description. Its construction is easily explained. A conical valve, opening outwards, is so closely fitted to an aperture in the upper surface of a boiler as to be perfectly steam-tight. This conical valve is firmly kept down by a weight (sliding upon a rod) exactly equivalent to the steam pressure to which the engine is limited as a maximum. Whenever that limit is exceeded, the weight is raised, the valve opens, and the steam escapes. By reason of the extraordinary high pressure required in the working of Savery's engines the adaptation to them of the safety-valve was all the more clearly desirable. Those engines, even at their best, had more than one striking defect or deficiency. Their consumption of fuel was excessive. They could never, without terrible risk of explosion, be built up of any great dimensions. And besides this, they were incapable of lifting water to a height of more than 90 feet, so that the pumping-out of a mine of unusual depth involved the working of engine above engine until the pit's mouth was reached. Nevertheless, with all its drawbacks, Savery's steam-engine was the first practical realization of what until then had been no more than fantastic day-dreams—his immediate predecessors, meaning De Caus, the Marquis of Worcester, Sir Samuel Morland, and Dr. Papin, producing, as John Farey says with ample reason, in his 4to Treatise on the Steam-Engine (p. 108), little better than the merest outlines, though all of them were, without doubt, ingenious philosophers.

To Newcomen, however, pre-eminently belongs the merit of having so availed himself of all that was especially excellent in the discoveries of Captain Savery and Dr. Papin, and, more than that, of adding to those

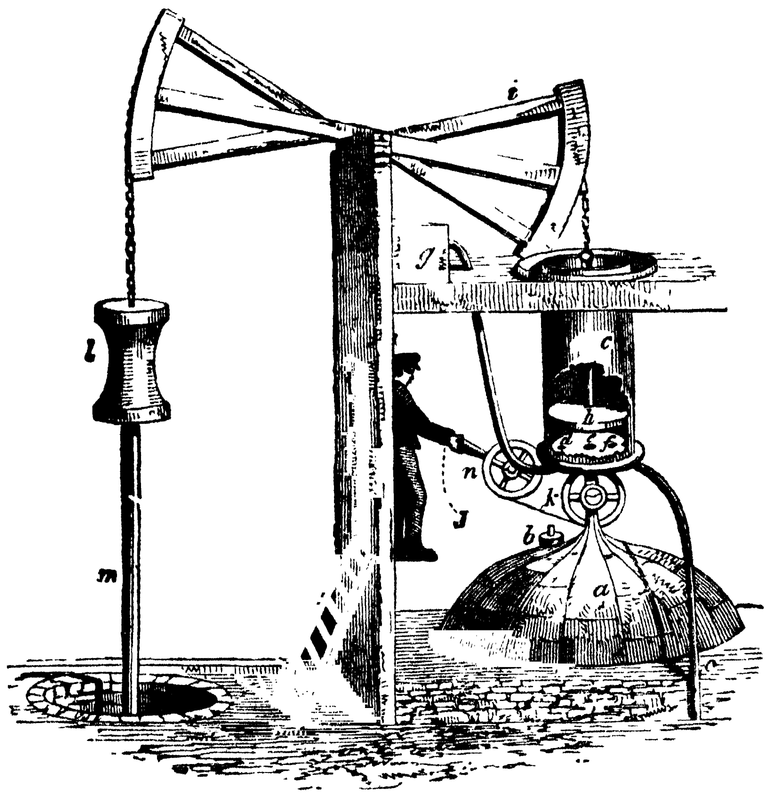

Fig. 6.—Newcomen's Atmospheric Engine.

inventions fresh and most important discoveries of his own, that a piece of mechanism (Fig. 6) was at length produced of such marvellous ingenuity, that for nearly fifty years together, it appeared to set at defiance all thought of its ever being superseded. Its paramount advantages were these :—It put distinctly apart those portions of the machine by which the steam was generated, and those other portions by which it was utilised as a motive power. Here, in one division were the boiler and furnace *a*, here in another were the piston and cylinder *c*. Beyond this, the vertical movement of the piston set in motion at the opposite extremity of a great rocking beam, like the beam in a pair of scales, whatever the engine was specially designed to keep going. Balanced upon a huge central pivot, that ponderous working beam had at either end an arch-head, from the upper part of which depended a chain that bent to the arch when it rose, and straightened perpendicularly down when it fell—the lowermost link of one of these chains, *i*, being connected with the piston-rod, and the lowermost link of the other, *l* and *m*, with whatever work the machinery was set in action to accomplish. Besides the distinctive characteristics which have here been specified, there were two other grand peculiarities, yet to be particularized, about the atmospheric engine of Newcomen, one of which was the contrivance of a clever little scapegrace, and the other of which was hit upon purely by accident.

As originally designed by Newcomen, the atmospheric engine, with a view to the better condensation of the steam by the application of cold water externally to the cylinder, was provided with a slightly larger outer cylinder, so that between the two, that is between the cylinder-proper and its outer covering, cold water might be the more readily introduced. Very shortly after this arrangement had been first brought into play, Newcomen remarked one day with surprise that one of the new engines worked with bewildering rapidity, and to all appearance quite independently of the usual condensing douche. On taking it to pieces to discover the cause, he then perceived that, from some casualty, there was a hole in the piston through which the water, according to custom suffusing the top of it to keep it air-tight, had trickled down or percolated, and by being thus brought into direct contact with the steam, had produced its instant condensation. Thenceforth the outer cylinder was swept away altogether and provision made for the injection under the piston (so soon as it had been driven to the top by the expansion of the steam) of a tiny jet of cold water, from the tank *g*, whereby the vapour being, so to speak, annihilated, a vacuum was instantaneously produced.

When Newcomen had got his atmospheric engine into thorough working order, it was found that it could be easily kept going with no more than a boy's attention. That however was imperatively required. Supervision of some kind was all-essential, the engine being liable otherwise either to stop altogether or to come to grief. Immediately upon the cylinder having been warmed by the vapour injected into it, upon the engine at any time being first started by the opening of the regulating valve, the steam mixing with the air already in it, forces another valve, opening outwards, at the extremity of a small tube at the bottom of the cylinder. By reason of the peculiar noise emitted in the escape thus of the steam and air intermingled, the orifice in question is technically called the blowing or *snifting valve* of the steam-engine. It is only necessary to listen once to the rushing expulsion of the united air and vapour thus, when an engine is being blown, as it is termed, before starting it, to recognize the reasonableness of that apparently ridiculous designation. Another valve, also opening outwards, and also at the bottom of the cylinder, goes by the name of the eduction valve, allowing escape thence from a tube through which the condensing water and the condensed steam are together ejected.

As the ponderous beam of Newcomen's atmospheric engine swayed upon the right and upon the left, as the piston rose and fell in steady succession, the duty devolved upon the Cock Boy, as he was called, to see alternately to the opening and shutting of the valves (*n k*), which were the vents or breathing places of the wonderful creature of fire and water and vapour and metal he was manipulating. Whenever the piston reached the top of the cylinder, the regulating valve had to be closed and the condensing valve opened. Whenever the piston reached the bottom of the cylinder those processes had to be reversed. Both wearied and fidgeted by the duty, at once irksome and monotonous, which was thus continually imposed upon him, one of these urchins, a Cock Boy named Humphrey Potter, eager, if he could, to escape from the drudgery, set his wits to work at last, to see whether he might not just possibly be able somehow to get over the difficulty. Watching the ponderous beam as it oscillated above him, steadily rising and falling upon his right hand and upon his left, as the piston rod and the pump rod alternately ascended and descended, Humphrey Potter—all the while, as in duty bound, pushing up and pulling down (see the dotted line at J), the levers that turned in due sequence the regulating and condensing valves, the opening and shutting of which alone kept the engine going—wondered to himself after long consideration, whether by connecting the beam and the piston-rod in this part and in that with certain strings and catches, the beam itself might not be got to do the labour of his own right hand. This extraordinary feat, in point of fact, he actually accomplished—thus, for the first time rendering the steam-engine as a piece of mechanism self-acting; insomuch that nothing was thenceforth required to be done in its regard, to keep it constantly at work, beyond ensuring the regular supply of water and fuel respectively to the boiler and the furnace.

Humphrey Potter's contrivance, called by himself a "scoggan," though perfectly effectual in its operation, was so rude and primitive in its character that it was little better after all than a tangled cat's-cradle of strings and catches. It naturally therefore gave place in the end to some more scientific and less complicated arrangement—there being substituted for it in 1718 by Henry Beighton, F.R.S., a metal bar or frame, which has been ever since known as the "plug-tree." Suspended from the main beam, this simple but important adjunct of the machinery bears upon it certain plugs which, in their rhythmic rise and fall, open and shut the regulating and injection valves with mathematical precision. Thus, in obedience to the suggestion of the little labouring hind, Humphrey Potter, was the steam-engine so far advanced on its road to perfection that, as Dr. Lardner expresses it, it became an automaton.

Newcomen's atmospheric engine is traceable back, probably, in the root-idea of it, not so much to the notion thrown out by Papin of working a piston in a cylinder by the pressure of the air above it in opposition to the vacuum beneath, as to an almost precisely similar proposal made some years previously by the inventor of the Air-Pump, Otto Guericke, the German philosopher. Wonderfully ingenious though many of Newcomen's own contrivances indisputably were, in building up and piecing together his marvellous apparatus, there can be little doubt of it that his chief merit, as its designer and fabricator, is recognizable in the consummate skill with which he combined into one whole the hitherto scattered devices of other earlier inventors.

During the interval which elapsed between the period in which he flourished and the advent of the great man by whom the steam-engine, as it is now known, may be said, not merely to have been brought to something like perfection, but to have been in a great measure virtually created, modifications of a more or less notable kind were made in the atmospheric engine. But, otherwise than as that engine was thus added to here and there, it remained to the last intact, the work of Newcomen. Meanwhile day-dreamers and experimentalists were still busily at work, either in idly forecasting or in practically preparing the way for a wider and wider development yet of the application of steam as a motive power, when, on the 19th of January, 1736, there was born at Greenock, in Scotland, one who was destined, by the exercise of a profound and comprehensive genius, to transform the whole world by the complete and perfect adaptation to its uses of the wonderful Power, the earliest whisper of which was breathed by the Æolipile of Hero of Alexandria.

James Watt, who takes rank by right of his achievements with the very greatest of the world's natural philosophers, was the son of a well-to-do ship chandler who, towards the close of a long and honourable career, lost, through a mistaken investment, nearly the whole of his possessions. Speaking of the difficulties which surrounded the great inventor's path at the very outset, his biographer and kinsman, James Muirhead, has quoted in his regard from Tennyson's "In Memoriam," and hardly with exaggerated emphasis, that wonderful passage in which the Laureate says that, "to shape and use" it, "Life is not an idle ore"-

> But iron dug from central gloom,
> And heated hot with burning fears,
> And dipped in baths of hissing tears,
> And battered with the shocks of doom.

Watt's great-grandfather—who died on one of the battle-fields of Montrose in the cause of the Covenant, and after whom, by the way, both the inventor and his father before him were in turn christened James—was a farmer of Aberdeenshire. His grandfather, Thomas Watt, on the other hand, was a Professor of Mathematics in Renfrewshire. It was after this latter, who attained some distinction in his day as a mathematician, that the child of the ship-chandler took, very clearly indeed, even from his earliest infancy. When a little creature of no more than six years of age, he was found one day working out a geometrical problem with a bit of coloured chalk on the marble hearth of the parental house-room. While yet a mere boy he contrived to make a miniature Electric Machine, with a sly shock from which he, once in a way, startled his young playmates. Before he was yet fifteen he had

Fig. 7.—James Watt and his Aunt.

twice read through, and thoroughly mastered, Gravesand's "Elements of Natural Philosophy." When still about that age his aunt, Mrs. Muirhead, upon one memorable evening (Fig. 7) reproached him sharply for his idleness.

"James Watt, I never saw such an idle boy!" she exclaimed indignantly. "Take a book at once and employ yourself usefully! For this last hour you have spoken not one word, but instead of that have taken off the lid of the kettle, and put it on again—have been holding a spoon over the steam—have been watching the vapour rising from the spout—have been catching and collecting the drops of water that steam formed when you held the saucer near it over the tea-cup. Are you not ashamed of wasting your time thus?"

Many years afterwards, when alluding to this incident, Arago remarked, in one of the noblest discourses he ever delivered before the French Institute, that the little James who was thus apparently idling his time away in front of the tea-kettle was, on the contrary, the mighty engineer preluding the discoveries by which he was to be immortalised. In fact the outcome of the child's meditations at that period was, before very many years had rolled by, visible in that astounding piece of mechanism which he, more distinctly than any one else who could be named, may be said, by the exercise of his profound intellect, to have called into existence.

So marvellous, in truth, was Watt's finished masterpiece, the steam-engine, that early in the following century Wordsworth observed, with reason, in its regard, that on seeing it, it is scarcely possible to divest oneself of the idea that it has life and volition!

Hearing this remark, which, in fact, had been addressed to him, Coleridge, with hearty assent, answered, "Yes, it is a giant with one idea!" Nay, in this matter the man of science has gone even beyond the two poets, for Bernard Belidor, in his treatise on Hydraulic Architecture, where he refers to the steam-engine as the most astounding of all machines, insists that there is no other the mechanism of which has such a distinct analogy with that of animals. "Heat," he writes (vol. ii. p. 324), "is the principle of its motion. In its pipes there takes place a circulation like that of the blood in the veins—having valves, besides, which open and shut themselves at right times. It feeds itself," he continues, "gets rid of its refuse at regular intervals, and draws from its own work all that is needful for its subsistence."

Preparing himself betimes for the enormous intellectual labours which were before him, the youthful son of James Watt, the ship-chandler of Greenock, and of Agnes, his wife, *née* Muirhead, taxed his naturally delicate constitution to such a degree by the severity of his studies that at frequent intervals he suffered agonies from headache. While yet in his eighteenth year he went to London, where he placed himself under the instruction of a skilled mathematical instrument maker. Having within little more than a year's time acquired extraordinary facility and precision in that exquisite craft, he returned to Scotland bent upon establishing himself there as quickly as possible in business. Accordingly, in 1757, being then twenty-one years of age, he settled down at Glasgow as Mathematical Instrument Maker to the University. There, in spite of his youth and his homely surroundings, as ostensibly a mere artificer, he rapidly won for himself a high reputation, not only as an extraordinarily dexterous handicraftsman, but as a most profound and original investigator of almost all the various departments of natural philosophy.

It was towards the close of 1763 that his attention was first directed, in the ordinary course of business, to a matter which opened up to him at once the grandest of all the many great achievements of his career. By a curious coincidence exactly a century had just then run out since the earliest practical notion of the steam-engine was, in 1663, promulgated by the Marquis of Worcester in the 68th of his Hundred Inventions. During the winter of 1763, a working model of one of Newcomen's atmospheric engines was placed for repair in the hands of Watt by Dr. John Anderson, the then Glasgow University Professor of Natural Philosophy. In taking it to pieces and putting it together again, with several alterations and improvements of his own, Watt realized for the first time the merits, which were numerous, but with those also the still more extraordinary deficiencies, of the invention. Out of the circumstance of this model being submitted to his examination, arose, one after another, in the lapse of years, the whole of his amazing discoveries and contrivances as the perfecter of the steam-engine. To him individually it is owing, as a matter of fact, that the atmospheric engine was, upon a large scale and at much less expense, transformed into a veritable steam-engine. He it was besides who first demonstrated by experiment the perfect practicability of the high-pressure engine.

Acting upon the hint given in the remote past by Hero's Æolipile, the Marquis of Worcester had originated the idea of a steam-engine by enabling vapour so to apply its elastic force to the surface of water in close vessels as to drive that liquid above the engine's level to a considerable elevation. Captain Savery had advanced a step further by the creation of a vacuum in vessels charged with steam, through the application of cold water to them externally. Newcomen and Cawley, again, had successfully carried out Dr. Papin's rather vague suggestions by establishing a direct connection, through an oscillating beam, between the piston working in the cylinder, pendant from one end of it, and the pump raising the water, pendant from its other extremity. Newcomen at the same time had imparted greatly increased efficiency to his atmospheric machine, it will be remembered, by substituting internal for external condensation, that is by the injection of a jet of cold water into the lower part of the cylinder. James Watt now, however, entered upon a series of inventions and discoveries by which the mechanism they were one after another applied to, was in the end completely transformed, and by right of which this supreme inventor and discoverer of the integral parts and constituent portions of the steam-engine as it now is, must, as a simple matter of fact, be said to have immeasurably surpassed the ablest of his predecessors.

Watt's earliest improvement in the steam-engine (Fig. 8) was the establishment of a perfectly Separate Condenser K,—one, that is, entirely distinct from, but directly connected with, the cylinder. Until then, at every stroke of the engine, there had been an excessive, in fact a doubly extravagant waste of power—first in cooling the cylinder sufficiently to produce a vacuum and then in reheating it sufficiently to enable the steam to exert its elastic driving-force on the piston. No sooner, however, had the brilliant thought occurred to Watt that the vapour might be condensed elsewhere just as readily as in the cylinder itself, than it became upon the instant equally clear to him that, although under the new arrangement the cylinder and the condenser would have to be brought at rapidly recurring intervals into direct communication with each other, they might be kept all the while at perfectly different temperatures—the condenser K at the

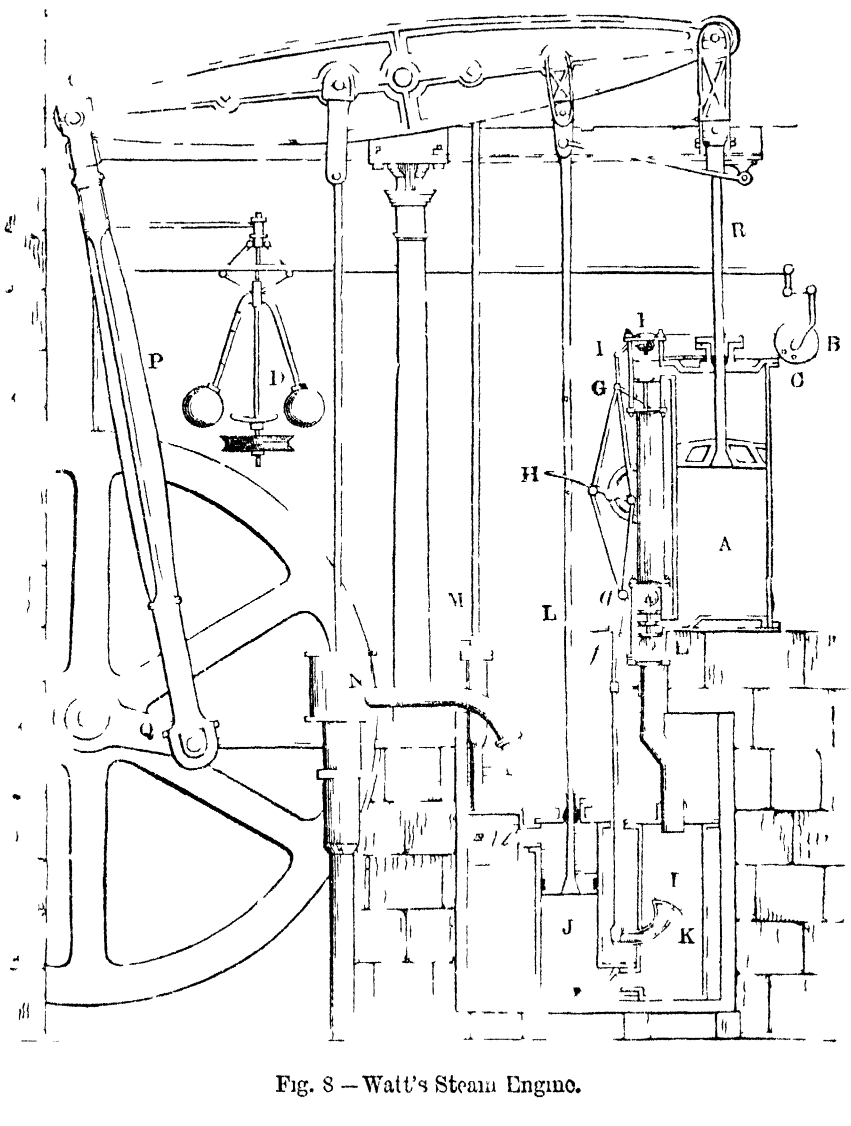

Fig. 8.—Watt's Steam Engine.

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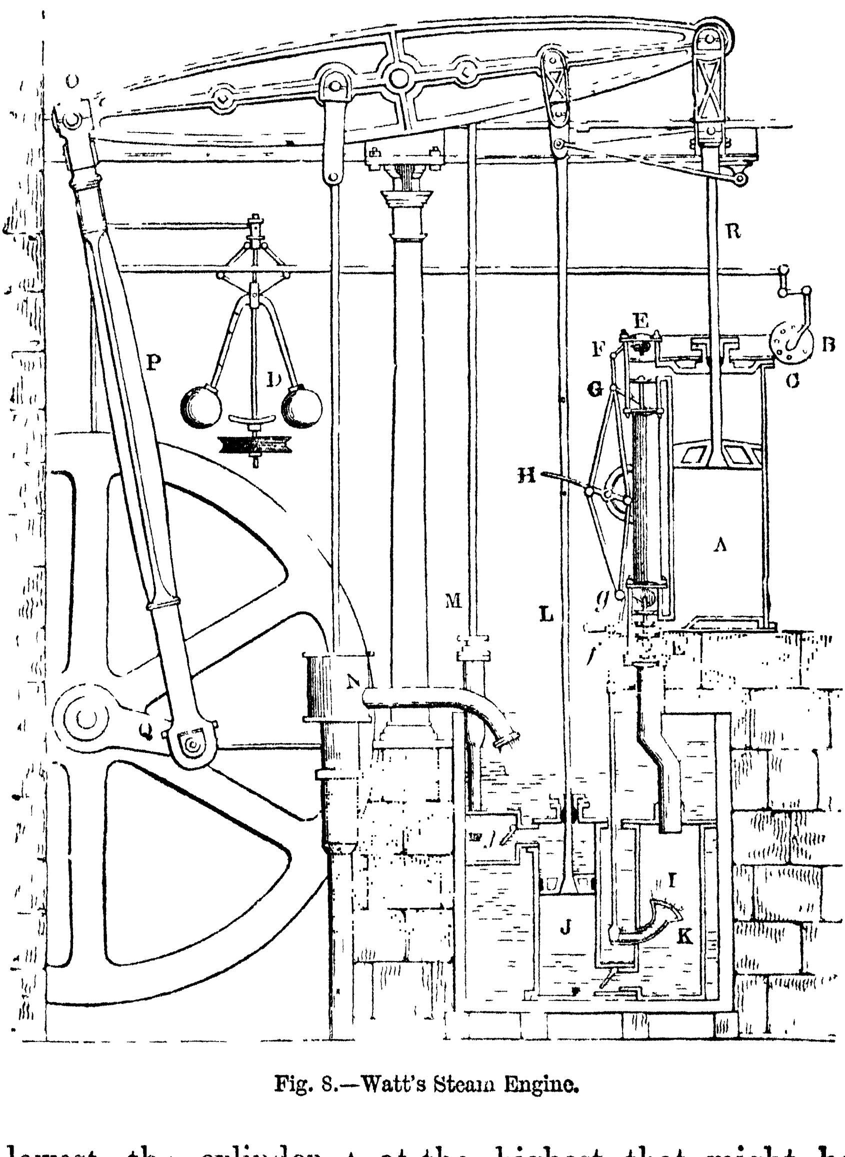

Fig. 8.—Watt's Steam Engine.

lowest, the cylinder A at the highest, that might be considered in any way desirable. Constructed upon this plan, the steam-engine consisted no longer of two but of three distinct divisions, all closely linked together, each with its distinctive appendages: the boiler or generator, the cylinder or applicator, the refrigerator or condenser. The effect produced by the first of these divisions was, curiously enough, exactly reversed by the last—the boiler, that is, forming steam out of water by heat, while the condenser formed water out of steam by cooling.

According to Professor Joseph Black, who was intimately associated with Watt at this period,—James Watt being then (in 1765) in his 29th year—the resplendent idea of Separate Condensation flashed upon the great inventor's mind in an instant, filling him as it did so with rapture. As he himself afterwards stated, it suddenly sprang out of his meditations one Sunday afternoon while he was taking a solitary walk in the Green at Glasgow, as nearly as possible just midway between the Herd's House and Arn's Well. Steam, he reflected, being elastic would expand and rush into any previously exhausted space; wherefore—this in fact being the revelation!—if he created a vacuum in a separate vessel, and then opened a communication between the vapour in the cylinder and that separate vessel thus already exhausted, precisely what follows would be the consequence! The steam rushing into the refrigerator would be there instantaneously condensed—creating at the same moment a vacuum in the cylinder, without any, even the faintest, diminution of the latter's temperature. Eureka! the solution of the seemingly insoluble problem was revealed.

Within three days—by the next Wednesday afternoon—Watt had rapidly worked out in his own mind the rest of the improvements which, as necessary consequences, grew out of that primary one of separate condensation. Knowing that the only possible way of making the steam-engine perfect was to see in the first place that the cylinder should always be as hot as the steam that entered it, and in the next that the vapour should be instantaneously chilled into extinction—the rest, precisely as he embodied it all in his first patent for a steam-engine (that of the 5th of January, 1769, the one six years afterwards renewed, in 1775, by Act of Parliament), followed as mere matters of course. To ensure coolness to his separate condenser, he not only placed it permanently in a large cistern of cold water, but caused a minute jet of cold water I, besides, to squirt perpetually inside it, so that the vapour might be instantaneously annihilated whenever it was admitted from the cylinder. While, to ensure the constant maintenance of the warmth of the cylinder, a jacket or casing, composed of some slow conductor of heat, was bound round it, the inner and outer cylinder being further enclosed at the top by a steam-tight cover, instead of being left, as hitherto, open to the atmosphere: the piston-rod working up and down, at the centre of this metallic cover, through a hole in it and in a stuffing-box, the well-compacted materials of which were tow plentifully saturated with an alternation of wax, oil, and grease. Not only by these means was the steam-heat of the cylinder maintained without any abatement, and friction almost completely got rid of, but, by the cylinder being encased at the top as well as at the bottom, steam could thenceforth be admitted at either end, so as to drive the piston up and down alternately.

Such in brief were the salient points in Watt's first or Single-Acting Steam-Engine. Modifications of it, here and there, were perpetually suggesting themselves to the inventor, one after another of which he developed into remarkable improvements. During the nine years which elapsed between 1767 and 1776 he was busily occupied, for example, in bringing to a successful application the principle of the Expansive Engine. By its exquisite operation the steam-valve was made to shut at the precise moment when the piston had gone any particular preconcerted distance in the cylinder, a quarter, for instance, or one third, or a half, the expansive force of the vapour accomplishing the rest and thereby economising in an admirable manner the mechanical force with which the piston was impelled. Five years after this subtle principle

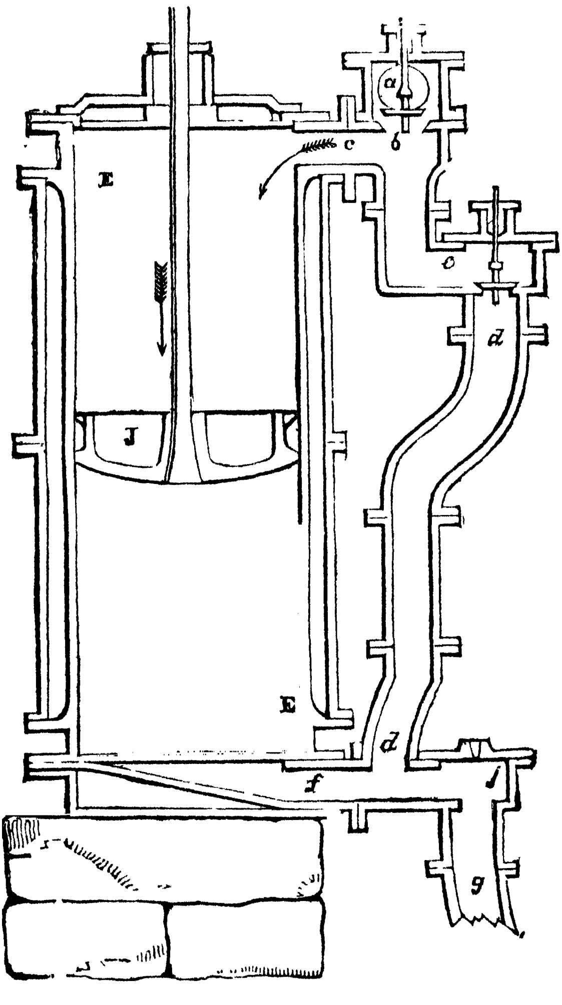

Fig. 9.—Cylinder and Piston.

was first practically applied by Watt, he, on the 25th of October, 1781, took out his second patent for a steam-engine, one especially designed for the production, from the piston's vertical action, of a revolving motion such as might set and keep going all kinds of rotatory machinery.

Watt's steam-engine of revolution, it was soon recognised, was an astounding advance upon the old pumping or "water-commanding" machines of previous inventors. Repeated attempts had been made by other experimentalists, but by the best of them ineffectually, to transmute the perpendicular action of the rise and fall of the piston-rod into the circular movement. Keane Fitzgerald was one of these; a second was John Stewart; while a third was Matthew Warborough: all of these vainly endeavouring to obtain from the great oscillating beam some revolutionary impulse. Watt's engine alone was found, when put to the test, to have triumphantly vanquished the difficulty, applying, as it did in the most efficient manner, continuous motion to the driving of revolving machinery.

As originally projected by the great inventor, the conversion of the up-and-down action into the circular movement was to have been accomplished by the application to the piston-rod of the crank, long familiar in the treddle of the turning-lathe and the spinning-wheel. Through the treachery, however, of a workman named Cartwright, who had been employed by Watt to make the model, before any right in the contrivance had been secured to the inventor, the secret was revealed and a patent wrongfully obtained by the engineer, one John Steed, to whom the rogue of an artizan had betrayed his employer's confidence. This was in 1779. But within two years from that date Watt, as if to show in a signal manner the fecundity of his constructive faculties, while at the same time carrying out his resolve to avoid all risk of litigation, had embodied in his second great specification for improvements in the steam-engine five other different methods for producing continuous rotatory motion from the rise and fall of the working-beam.

Conspicuous among these was a beautiful arrangement of Watt's, entitled by him the Sun and Planet Wheels, both of them toothed wheels, the smaller or planet one, which was incapable of revolving, being fastened on the end of a Connecting Rod which, in rising and falling to the rise and fall of the working beam, travelled, tooth by tooth, round the circumference of the larger or sun wheel, the latter being fixed upon the axle of the fly-wheel, which was thus set rapidly in revolution. So efficiently did this ingenious arrangement answer its purpose that it was only superseded by the substitution of Watt's original adaptation of the crank to the purposes of the steam-engine on the expiring in due course of Steed's fraudulently obtained patent.

Another most important improvement was the replacement by the great inventor, through his third patent for the steam-engine, dated the 12th of March, 1782, of the two cylinders and pistons working alternately, by the double-acting piston which the steam impelled now upwards now downwards, as either end of the cylinder in turn was brought into communication with the boiler and the condenser. Perhaps the most remarkable testimony of all, however, at once to the comprehensiveness and to the exquisite adaptability of Watt's genius as a mechanician, was that afforded by his masterly contrivance for ensuring to the rod of the double-acting piston in its rise and fall a perfect maintenance of the perpendicular. Seeing that, in the double-acting engine, the piston would have to push the working beam up as well as to pull it down, and that, thenceforth, the connection between the two must, therefore, be accomplished by attaching the piston-rod to a piece of rigid metal upon the beam itself, without any intervention as hitherto of a flexible chain alternately lapping round and pendant from the arch-head as it ascended and descended, it became obvious that the problem to be solved was, how to keep the piston-rod in its rise and fall in a perfectly upright position, though the beam-end to which it was attached in that same rise and fall described the arc of a circle! Bewildering though the difficulty might have appeared to others, it was overcome by Watt with surpassing ingenuity in his 4th patent for the steam-engine, that of the 28th of April, 1784. A rack upon the upper extremity of the piston-rod, working in a toothed arch fixed upon the oscillating beam, was found to be inapplicable, because the absence of friction and the perfectly smooth working of the piston in the cylinder

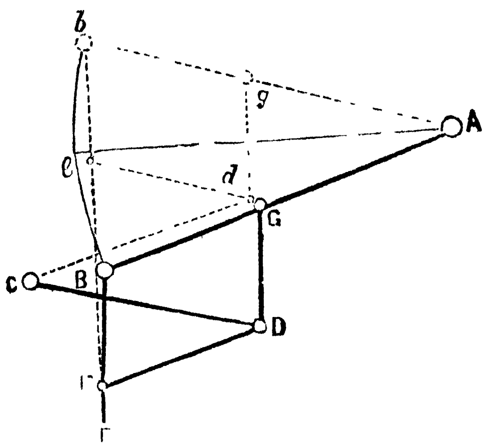

Fig. 10. - The Parallel Motion.

were absolutely requisite. Instead of resorting to any such means, Watt, in 1784, perfectly solved the problem with his lovely contrivance (Fig. 10) of the Parallel Motion.

Consisting of an arrangement of five jointed rods, including a parallelogram, it was as Watt himself expressed it, a perpendicular motion derived from a combination of motions about centres. Pre-eminent among all the mechanical inventions of the great engineer, it has won to itself unmeasured admiration. Observing its action as a delicately articulated parallelogram, it is impossible not to recognise the reasonableness of Arago's remark, that "at each ascent and descent of the piston its angles open and close with the sweetness—I had almost said the grace—which charms you in the gestures of a consummate actor." Three of the four angles, it will then be seen, describe circular arches; while the fourth, which is the one attached to the piston-rod, moves as nearly as possible in a straight line perpendicularly.

Besides this wonderful adaptation by Watt of the parallel motion to the double-acting steam-engine, he supplemented his ingenious contrivance of the sun and planet wheels with another, a ponderous one of metal, of large circumference, known as the Flywheel—by the momentum of which the force of each revolution was sustained throughout. Giving, in fine, a perfecting touch to the whole, Watt yet further hit upon an arrangement in connection with the Flywheel by means of which the energy of its progress was under all emergencies exactly proportioned to the resistance of the work it had to accomplish. This was effected through the medium of the admirable piece of mechanism (Fig. 11), called the Governor, by the movements of which the axle of the flywheel was enabled to regulate to a nicety the opening or closing of the throttle valve—thereby, exactly in accordance with the need of the engine at the moment, increasing or diminishing the supply of steam to the cylinder. Through the agency of the governor, for example, whenever the flywheel increased its velocity it so acted

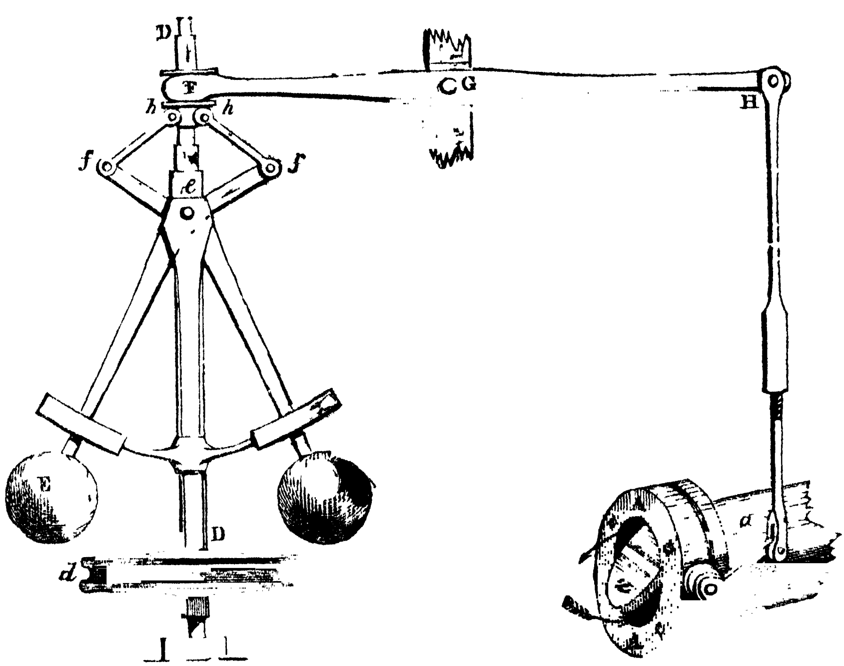

Fig. 11.—The Governor and the Throttle Valve.

upon the throttle valve in the steam pipe as to diminish the supply of vapour from the boiler and, in so doing, of course, to slacken the motion of the piston : while, on the contrary, whenever the velocity of the flywheel dwindled, the passage for the admission of steam to the cylinder was enlarged and the motion of the whole machine in consequence proportionately accelerated.

Similarly Watt attached, only in a more direct manner, to the axle of the flywheel another apparatus of marvellous ingenuity and yet also of marvellous simplicity, termed the Eccentric, by which the valves of the engine were opened and closed with mathematical precision precisely at the right moment. A circular metallic plate—this was the Eccentric!—having a square hole cut through the face of it just midway between its centre and its circumference, was so keyed on, by that square hole, to the axle of the flywheel, that when the latter revolved, the centre of the metal circle revolved round it. Loosely fitted about the rim or edge of this circular plate—so loosely that the disc could move within it quite independently—was a metallic collar, from one side of which extended a two-pronged arm having attached to its extremity an ingenious arrangement of levers. Consequent upon the movement of these levers, in obedience to what is called the "throw" of the eccentric, meaning, that is to say, exactly double the distance from the centre of the disc to the centre of the shaft round which it revolved, the valves opened and shut at any required position of the crank and flywheel, and therefore as a matter of course at every required position of the piston in the cylinder.

So effective altogether was the advance made by Watt in the application of steam as a motive power, that whereas before his time the pressure employed was one of 4 lbs., he rapidly advanced it to 8 lbs. and even to 12 lbs., condensing engines being often worked

Fig. 12.—Statue of Watt in Handsworth Church.

now-a-days at as much as 25 lbs. or even 30 lbs. pressure. Such, moreover, has been the extraordinary skill arrived at in the construction of boilers, that a pressure in them of 200 lbs. may be ventured upon to-day with as absolute security as one of 4 lbs. might have been formerly. Virtually the history of the steam-engine closes with the labours of Watt, whose life of 83 years (from 1736 to 1819) marks the interval within which it was brought to perfection by his master hand. For, true though it be that the steam-engine is little more than the combination of a great number of perfectly distinct contrivances suggested, now by one, now by another, James Watt has an undisputed right to be regarded as beyond all comparison its chief inventor. Beginning life in a provincial town of Scotland as an obscure artizan, he came to be regarded by the whole world, long before his death, not only as an illustrious philosopher, but as one of the greatest practical benefactors of the human race that ever existed.

It may seem a small matter to start with, that a pint of water can be evaporated by a couple of ounces of coal. But, remembering that, in the process, that pint of water is magnified into 216 gallons of steam, which has within it an elastic force capable of lifting 37 tons a foot high, and beyond that an expansive power exactly equivalent in value—the fact remains that 74 tons can be raised a foot high with the help of two ounces of coal and a pint of water! To enable the fuel and the water, however, to accomplish this (and how much more!) they have first of all, of course, to be supplied in sufficient quantities like so much food to Watt's wonderful automaton.

Let the coal once be properly ignited in the furnace,

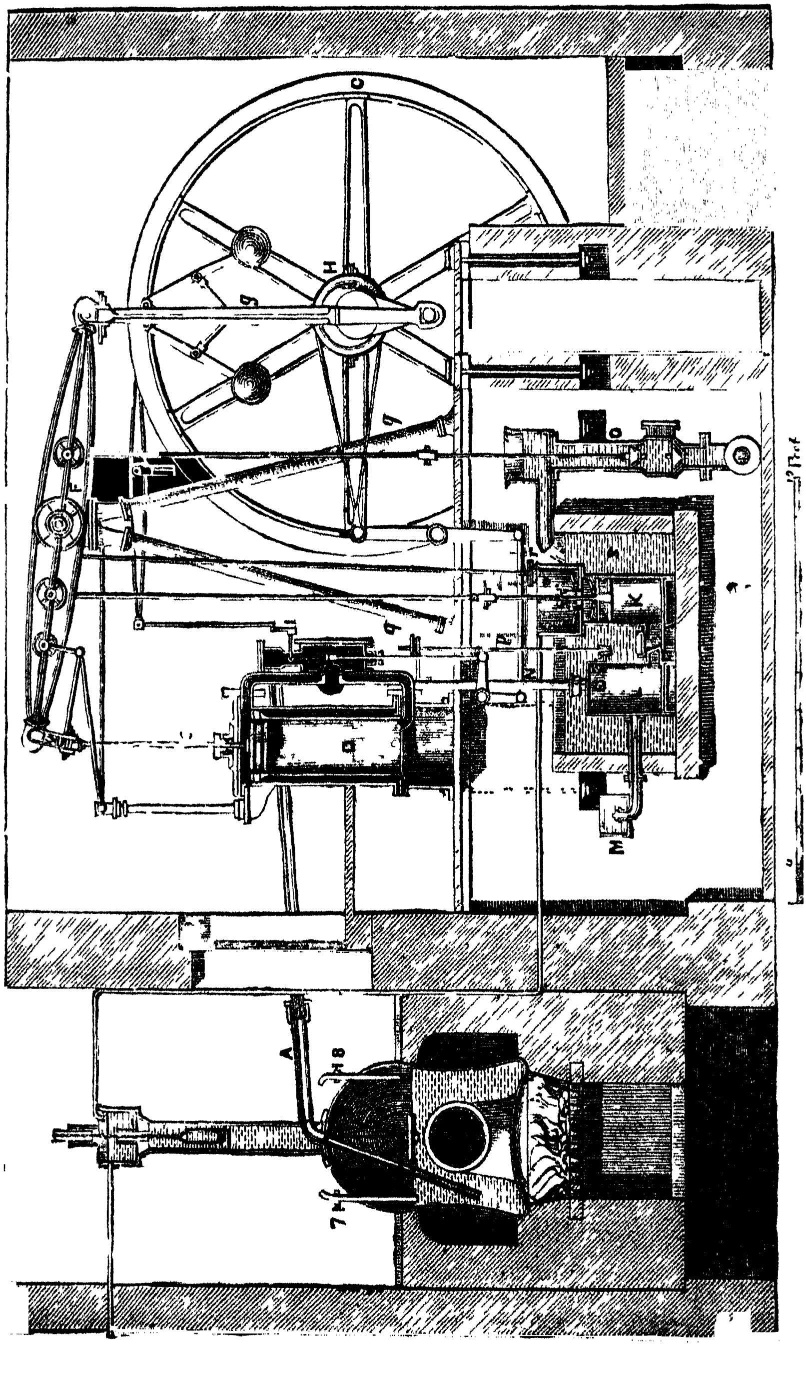

Fig. 13.—Watt's Double-Acting Steam Engine.

and the water fully heated in the boiler, and at a touch from the hand of the engineman, the whole of the complicated and exquisitely balanced machinery of the Double-Acting Steam-Engine (Fig. 13) is set a-going! Under the furnace is the ash-pit—through it and around it are its flues and conduits. Conspicuous on the boiler are its pair of gauge-pipes 7 and 8, its blow-off cock, and its safety-valves—less noticeable in their way are its fuseable plugs, its vacuum valves, and its feed apparatus. Most prominent, there, of all is the steam-chest or dome B surmounting it, through which is supplied from the boiler the vapour which is to the whole machine something more even than the breath of its nostrils, circulating as it does through all its ducts and secret ways as the blood in a living creature circulates through its veins and arteries. From the steam-chest B to the cylinder D, the channel through which the vapour is shot into the latter alternately above and below the piston, is the steam-pipe A, inside which, as its apparatus, are the stop-valve, the cut-off or expansion-valve, and the throttle-valve or regulator. Flanking the cylinder, as the section of it shows (Fig. 9), are its steam passages, the ports or nozzles of which are in turn opened and closed, now above, now below, by the induction and eduction valves, or when the two are in one by the automatic valve or four-way cock, invented in 1720, by Jacques Leupold.

Whenever the steam-engine is non-conducting or high pressure, the waste vapour is liberated from the cylinder into the atmosphere through the exhaust or blast-pipe, the latter being, with immense advantage in the furtherance of combustion, discharged straight up the chimney in the instance of the locomotive. Completely enclosed in the cylinder, the piston throbs inside it with the regularity of a heart's pulsations, driven up and down by the steam pressure from below and from above, the piston-rod, in its swift rise and fall, working glibly through the air-tight and steam-tight hole in the cover, as well as through the stuffing-box below of well-compacted tow saturated with oil and tallow. As for the cylinder, it also, no less than the piston within it, is kept perpetually at the same high temperature as the steam thrown into it, not merely by the circumstance of its being spared even an occasional chill, thanks to the system of separate condensation, but thanks also to its being provided with a jacket or outer cylinder filled with hot vapour, and covered with a clothing or cleading of mingled felt and wood. Unnoticeable at the bottom of the cylinder is the escape or blow-through valve, opening outwards and sustained by a spring through which any chance accumulation of air or water in the cylinder may be expelled. As for the condenser, which is both air-tight and steam-tight, no less than the cylinder, it is immersed in the cold-water tank or cistern T so as to ensure it perfect refrigeration. At the bottom of it is the snifting-valve, which sneezes outwards into the atmosphere any superfluous windy moisture. Within it, spraying upwards from the injection-valve, is the tiny jet which lays the ghost every other moment of the whiff of steam, admitted for the express purpose of being thus laid, alternately from above and below the restless piston that is perpetually flying up and down in the cylinder.

Rising into view from its secret seclusion is the vacuum gauge, which shows at a glance the relative pressure of the condenser and of the atmosphere. Working continually on a good-riddance principle, at the core of the condenser is the air-pump, which persistently discharges in one breath whatever vapour, air, and water are there lingering, and the residuum of which, under its influence, goes to swell the hot-well from which the boiler receives its supplies. Rising and falling in the arc of a circle immediately above the perpendicular ascent and descent of the piston *e*, by which its movements are directed, is one of the two extremities of the well-balanced working beam, the connecting links between these antagonistic and apparently irreconcileable forces being the celebrated contrivance of the Parallel Motion. From the opposite extremity of the working beam depends from its strong pivot the connecting rod, the other end of which is fastened on to the crank, which through the medium of the crank-shaft sets the equaliser of the whole movements of the machine, meaning the huge and ponderous flywheel C, upon its gyrations. Keyed on to the very centre of the flywheel at its axis is the eccentric H, by which the action of the crank itself is directly reversed—the circular motion being transformed by an arrangement of levers into the rectilinear, whereby the eduction and induction valves in the cylinder are opened and closed alternately.

Meanwhile, completing the circuit of the whole, by linking together the opposite extremities of the intricate mechanism of the steam-engine, the twirling balls of the governor—which are compelled to revolve round the central spindle more swiftly or more slowly in proportion as the revolutionary movement of the flywheel is slackened or accelerated—so act upon the throttle-valve in the steam-pipe that the speed of the engine is quickened or delayed exactly according to its requirements. From what has been said it will be perfectly obvious that the primary elements and opposite poles of the steam-engine are the cylinder and piston on the one hand and the crank and the mainshaft on the other—the cylinder containing the steam — the piston, the crank and the mainshaft transmitting and applying its energy.

Hidden away inside the complex piece of mechanism, with but faint indications, here and there exteriorly, of their whereabouts, are the numerous valves by which communication between the various parts of the structure is being perpetually opened and closed in rapid succession. These momentary restrainers and releasers of the vapour—which is the life-blood of that all but animated creature the steam-engine—act in very different ways indeed, as may be seen at a glance when they come to be examined. Some, such for example as the clack valve, are raised like the lid of a box upon hinges, the leather of which they are composed being a trifle larger than the aperture they are designed to shut, and weighted besides upon the other side with a metal plate rather smaller than the orifice. Others, such as the throttle-valve, turn midway upon an axis. While others, yet, lift bodily up and down like the lid of a pot or kettle, these latter being known as conical steam-valves, or more ordinarily as spindle-valves. There is the slide-valve, again, which opens and closes after the manner of a box-lid running in grooves, or like the sash of a window. On the other hand, the cocks of a steam-engine invariably act with a circular movement: the four-way cock of Leupold, already mentioned, having been perfected in 1801 by Joseph

Bramah by being made to revolve continually in one direction.

Since the time of Watt his finished masterpiece has been supplemented, now here, now there, by an occasional improvement; such for instance as by the employment in it of super-heated steam, or as by the substitution of steel for iron in different parts of its machinery. But, virtually, when James Watt died on the 25th of August, 1819, the grand achievement of his life was left complete, being, already then, not merely as a phrase but as a fact, a finished masterpiece. As many as 10,000 of his steam-engines had been turned out under his direction by that time from Boulton's great manufactory at Soho, near Birmingham. and were then actually doing the work of three or four millions of men or of 500,000 horses—with an annual saving thereby of £12,000,000 or £13,000,000. During the very last year of his life there were produced at Soho as many of his machines as would do the work of 100,000 horses, thereby effecting an economy of animal labour to the value of fully £3,000,000.

A little more than a century ago, dating from the time when these words are written, Watt, in 1781, invented his crowning marvel of the double-acting engine, that is of the perfected steam-engine. Within that same year, 1781, Dr. Erasmus Darwin published his "Botanic Garden," in which he set forth these prophetic words :—

> Soon shall thy arm, unconquered Steam, afar
> Drag the slow barge or drive the Rapid Car,
> Or on slow waving wings, expanded bear
> The Flying Chariot thro' the fields of air.

Little did the writer of those lines imagine, when he jotted them down on paper, that there was then lying in a poor collier's hovel near Newcastle-upon-Tyne, in the obscure village of Wylam, an infant, who, within less than half a century afterwards, would realize one half at least of that apparently most wild prediction. George Stephenson, born on the 9th of June, 1781, the son of an illiterate working-man, as completely, in 1830, distanced all other competitors with his historical locomotive, "The Rocket" (now preserved as a relic in the Museum of Science at South Kensington), as "Flying Childers" distanced all other racehorses. Richard Trevithick had, as far back as in 1802, contrived an engine for travelling on highways, but not until "The Rocket" was furnished by George Stephenson (Fig. 14), with its multitubular boiler, and had its steam-blast discharged up its chimney C, thereby doubling (literally in one breath) its combustion and its general efficiency, was the steam-engine, from being stationary, rendered rapidly moveable. Thenceforth, as a Power, it was as obedient to man as to the Centurion in the Gospel were his soldiers, unto one of whom he says, "Go, and he goeth;" and to another, "Come, and he cometh;" and to another, "Do this, and he doeth it."

A single pound weight of coke, it was then soon made manifest, was capable, in a locomotive, of evaporating five pints of water, the steam thus generated being able to draw two tons' weight one mile in two minutes —whereas four horses harnessed to a stage-coach upon a high road could only draw the same weight the same distance in six minutes. Otherwise, a bushel of coal was thus enabled to do the work of 100 horses. With four tons of coke, the value of which is £5, a train eighty tons in weight, it was found, not so very long after the construction of "The Rocket," could convey 240 passengers with their luggage from Liverpool to Birmingham and back, that is 190 miles both ways, in six hours and a half, stoppages included; whereas the same work could only be accomplished on the high road with the aid of twenty stage-coaches drawn by 3800 horses, the journey taking not six and a half hours both ways, but twelve hours each way, stoppages included.

Lightness being absolutely essential in the Locomotive, its perfecter, George Stephenson, when constructing it, dispensed altogether with the cold-water cistern, the condenser, the air-pump, the cold-water pump, and their respective paraphernalia, the machine thus resolving itself into a strictly non-condensing or high-pressure engine, consisting merely of furnace, boiler, chimney C, cylinder, piston H, and valves. Since it was first set fairly running, more than 19,500 miles of railway have been opened in the United Kingdom, and upwards of 38,800 more in our colonial possessions,—showing a magnificent aggregate of more than 58,000 miles of railway already constructed in the British Empire.

Reverting, however, from the Railway to the Locomotive and from the Locomotive to the steam-engine, which is the subject-matter of which I am here treating, I would instance side by side one of the most gigantic, and one of the minutest steam-engines that have ever been fabricated. A working model was produced in 1842, weighing less than half an ounce; including the boiler and its appurtenances, weighing altogether an ounce and a quarter. Steam was generated in it by means of a tiny spirit-lamp, its single charge of water enabling it to work for nearly half an hour with a velocity equal in a minute's time to 500 revolutions. Such was the miniature character of the machinery, that the whole admitted of being deposited in a moderately sized pill box. In startling contrast to this Lilliputian steam-engine was the Brobdingnagian one produced two years afterwards, that is in 1844, the

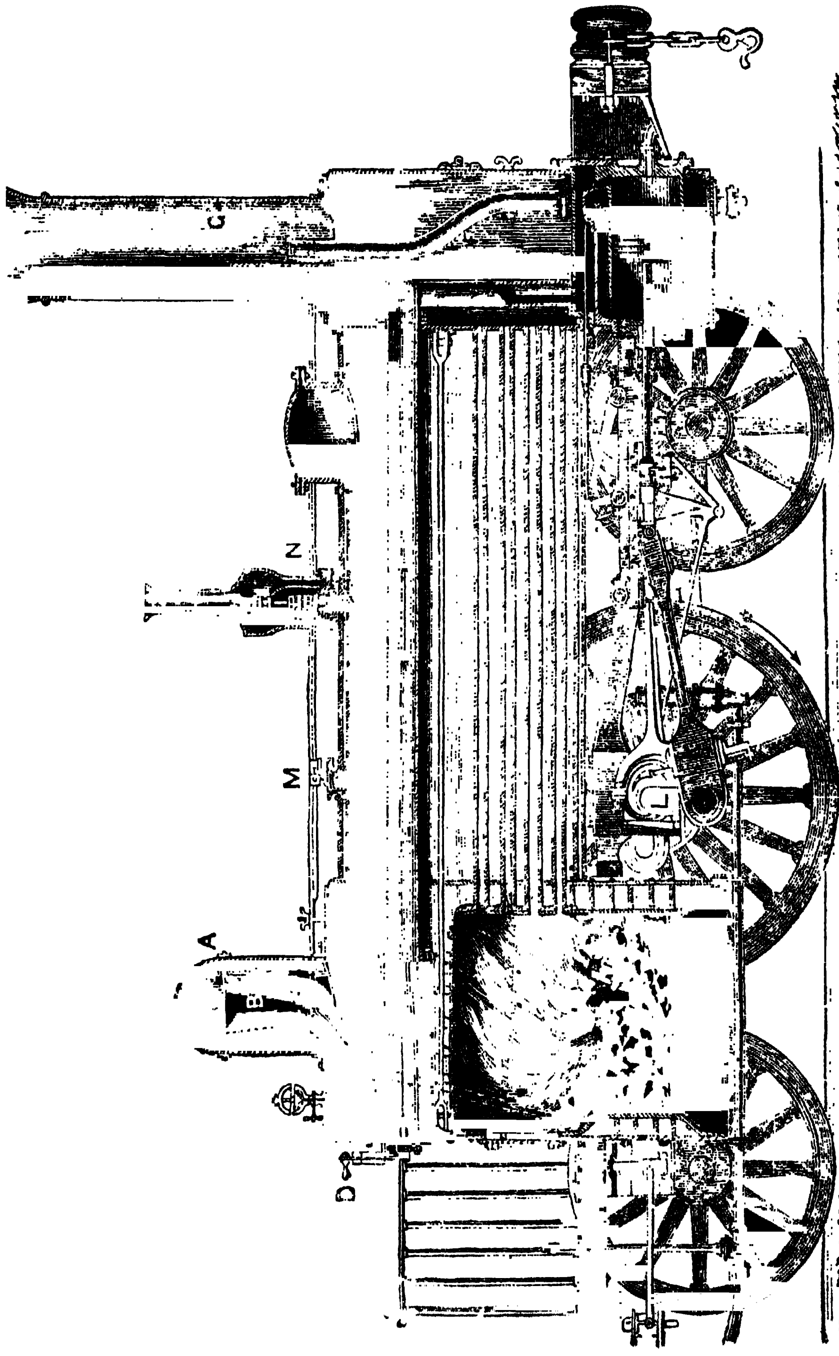

Fig 14 —Section of Locomotive.

object to which it was applied being the drainage of the lake at Haarlem. This mammoth steam-engine had a cylinder so enormous that it was 144 inches in diameter, the largest ever cast for any purpose. In its casting, it required no less than 25 tons of molten metal, which was, nevertheless, run into the mould in less than six minutes.

Within this last hundred years the steam-engine has been built up and brought to perfection by British inventors. The first of the Modern Seven Wonders of the World sprang into existence in this country. Our island is the stand-point from which this more than Archimedian Power has moved the whole earth. Thanks to James Watt beyond all others, it has become, as Lord Jeffrey wrote on the morrow of the great inventor's death, "a thing stupendous alike for its force and its flexibility—for the prodigious power it can exert, and the ease and precision and ductility with which it can be varied, distributed, and applied. The trunk of an elephant which can pick up a pin or rend an oak is as nothing to it. It can engrave a seal, and crush masses of obdurate metal before it—draw out without breaking a thread as fine as gossamer, and lift a ship of war like a bauble in the air. It can embroider muslin and forge anchors, cut steel into ribands, and impel loaded vessels against the fury of the winds and waves." As Lord Brougham has said in the imperishable words graven upon the granite pedestal of Watt's colossal monument in Westminster Abbey, he, as the

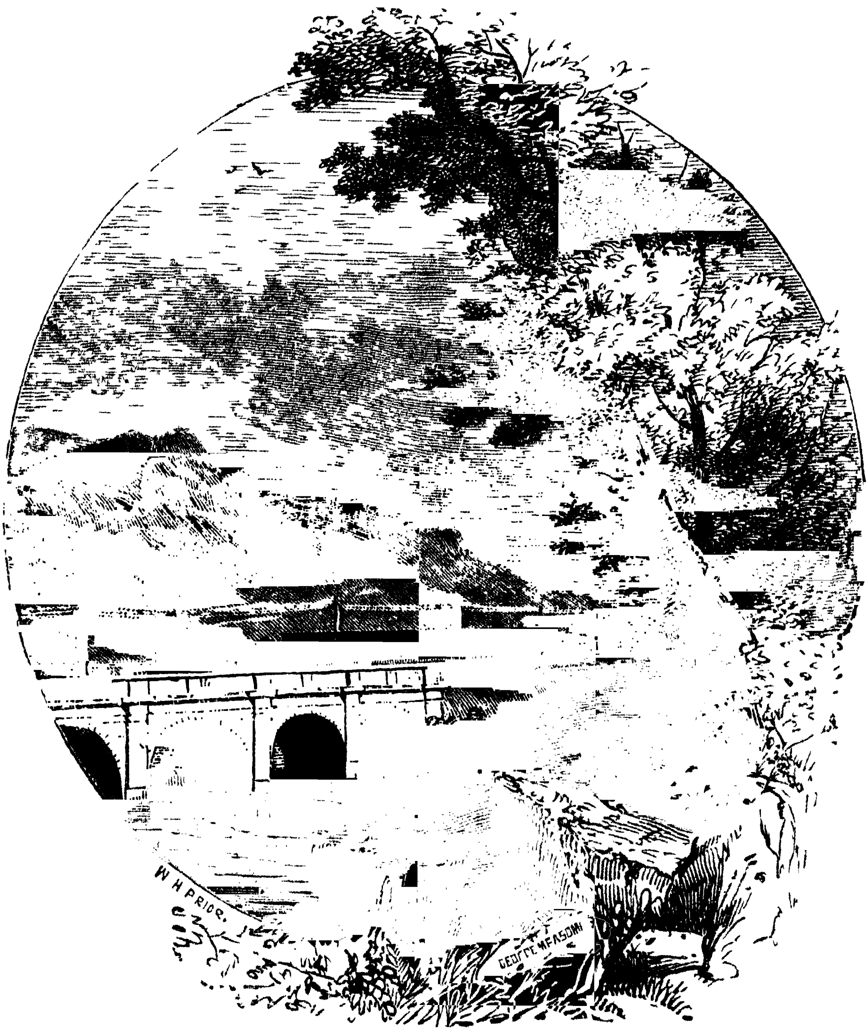

Fig 15 – The Present Locomotive and Train

improver of the Steam-Engine, "enlarged the resources of his country, increased the power of man, and rose to an eminent place among the most illustrious followers of science and the real benefactors of the world." So stupendous is the power exercised by the steam-engine, that more than thirty years ago it was calculated by a writer in the "Quarterly," that its employment, in Great Britain alone, was equivalent even then (in 1858) to the manual labour of upwards of 400,000,000 men, or more than double the number of males then in existence. As a wonder-working automaton it is as beneficent an agent to man as the monster of Frankenstein was the reverse to its creator.

II.—THE ELECTRIC TELEGRAPH.

"One touch of nature makes the whole world kin."—SHAKSPEARE.

ROBIN GOODFELLOW says confidently in the "Midsummer Night's Dream," "I'll put a girdle round the earth in forty minutes." That Puck of modern civilisation, the Electric Telegraph, could now-a-days just as easily *do* this as say it. And, in accomplishing its marvellous flight, it would be well up to time besides, with merely the thrill of an acid and the click of a needle. Yet—to express the matter tersely in a sentence — the Wonder thus achieved is nothing more, after all, than the bringing together and the putting in a manner into direct antagonism with each other, of two of the great forces of Nature: Electricity and Magnetism.

Many centuries before the dawn of the Christian era, the electric and magnetic forces had both of them been discovered. Not until very recently, however, not in fact until the commencement of the reign in which these words are written, was that dexterous union of them effected, by means of which people on opposite sides of the globe are, as a matter of every day occurrence, brought into instantaneous communication. Remembering this, it is curious to recall to mind the statement set forth in one of those queer old legends with which Greek mythology abounds, that the earlier known of these rival forces, the loadstone, was first brought to light actually by—the delay of a message!

A certain classic bumpkin, in fact, named Magnes—from whom the loadstone in consequence is reputed to have derived its designation as a Magnet—having been despatched on one occasion (so runs the tale) as the bearer of important and urgent tidings across Mount Ida, found, to his immense bewilderment, that his pace was retarded by the unaccountable circumstance that the hobnails with which his boot-soles bristled, clung tenaciously at every step to the dark ore of the ground he was traversing. As a matter of fact, however, not fable, the mineral in question was, for fully a thousand years before the coming of the Redeemer, popularly known as an article of commerce readily procurable in Magnesia, whence, far more probably than from Magnes, arose its familiar appellation. Certain it is, moreover, that from time immemorial both the Chinese and the Arabians were perfectly well acquainted with its existence.

Everybody bears in recollection, no doubt, the wonderful incident related in the "Thousand and One Nights," by Sindbad the Sailor, of his having suffered shipwreck through the vessel in which he was sailing being drawn out of her course by the Loadstone Rock, to which in the end, as the voyagers approach it more nearly, every bolt, nail, and rivet flies from the ship's timbers, leaving the loose planks, and crew, and rigging for an instant afloat upon the surface of the deep, to be then summarily submerged.

Thales of Miletus, one of the Seven Wise Men of Greece, founder of the Ionic Philosophy, and subdivider of the year into 365 days, is understood to have been the first to recognize that amber when rubbed reveals a property which, after for a moment attracting, the next instant repels, such light objects as feathers, straws, and withered leaves. Amber, being in Greek *electron* (*ἤλεκτρον*), that mysterious something—which is considered, now, to be latent in all matter—has acquired ever since in every civilized language the name of electricity. So universally is it diffused that not an action takes place without its being either appreciably or inappreciably called into existence.

Stroke a cat's back with the palm of your hand, draw briskly between your fingers a tag of silken ribbons, erase a pencil-mark from a sheet of paper with a piece of india-rubber, polish a stair-rail or a gun-barrel with a silk handkerchief, and that mystic property which is termed, for want of a better phrase, the electric fluid, is elicited by the friction in more or less abundance.

Perhaps as instantaneously illustrative of this as anything that could be named, is the rubbing of a clean glass tube, such as a lamp chimney, with a dry hand, or of a stick of sealing-wax with a dry bit of flannel, when upon either being presented to such atoms as I am about to name, there will, in the instance of the sealing-wax, be first attracted and then repelled, and in the instance of the glass tube, first repelled and then attracted, trivial substances like particles of bran or tiny fragments of paper. From the peculiarity just noticed, glass and wax are said to be in opposite electric conditions—that of the sealing-wax being defined as negative or resinous electricity, and that of the glass tube as positive or vitreous electricity. Another distinctive peculiarity of this wonderful force in matter has yet to be noted, namely, that whereas its two states are to all appearance diametrically opposed or conflicting, they are nevertheless so far intimately allied with each other that they are invariably co-existent. Thus, for example, in the very act of the glass tube being rubbed with silk, the former becomes positively and the latter negatively electrical. While, on the other hand, when the sealing-wax is rubbed with flannel, the former becomes negatively and the latter positively electrified.

Consequent upon these phenomena, Charles Dufay, in 1733, propounded his theory as to there being two distinct kinds of electricity, which he was the first to distinguish respectively as vitreous and resinous—such bodies as are similarly electrified repelling each other, and attracting such as are oppositely electrified. In direct antagonism to this dual theory, was the theory as to there being a single electric fluid, first suggested to the Royal Society in 1747 by Sir William Watson, but in the following year more clearly demonstrated and systematised by the American philosopher, Dr. Benjamin Franklin. According to this later and simpler theorem any substance in which the single electric fluid was in excess was regarded as *plus* or positively electrified whereas any substance in which it was deficient was regarded as *minus* or negatively electrified.

Reverting, however, for a moment to the elementary truth already notified in regard to the electric telegraph, or, as it ought more correctly to be termed, the electro-magnetic telegraph—that it has sprung into existence out of a combination of the two great natural forces of electricity and magnetism—it is curious to remark how few and far between are the evidences of any knowledge of either to be found scattered, on the one hand, here and there through classical literature, and on the other through the records of the Middle Ages. Theophrastus, who flourished just three hundred years after Thales, was the first to direct attention, incidentally, to what we should now call the electric properties of tourmaline. While, fully as many centuries afterwards, the elder Pliny was the next writer of any eminence to make especial allusion to similar phenomena. No more than the merest casual references, also, are to be met with in the whole range of the Greek and Latin classics, to the no less incomprehensible and equally marvellous powers appertaining to the loadstone. While as for the magnetic needle, which derives from that ore by touch its mysterious property of pointing perpetually northwards, Alexander Neckam, in a treatise published as early as in the twelfth century, speaks very plainly, indeed, of the use, even then, of the mariner's compass.

Cardinal Jaques de Vitry, again, in the eighty-ninth chapter of his "History of the Crusades," writes of it, not later than in 1218, as all-essential to those who navigate the ocean. Besides this, Guiot de Provins, the French poet, sings of it nearly about the same time, as later on, before the century has run out, does the Italian poet, Guido Guinizelli. Obviously, therefore, as may now be seen at a glance, no serious claim can be advanced which would fix upon Flavio Gioia the glory of having, in 1310, first constructed the mariner's compass. Whensoever, and by whomsoever, that priceless boon for the navigator may have been originally fabricated, certain it is, that by the close of the fifteenth century, distinct preparation had been made for the readier application, independently of each other, of the two forces, by the eventual combination of which, but little more than two hundred and fifty years afterwards, the electric telegraph was brought to perfection. For, not only had the dip of the needle been discovered and provided against in 1576 by Robert Norman, a mathe-

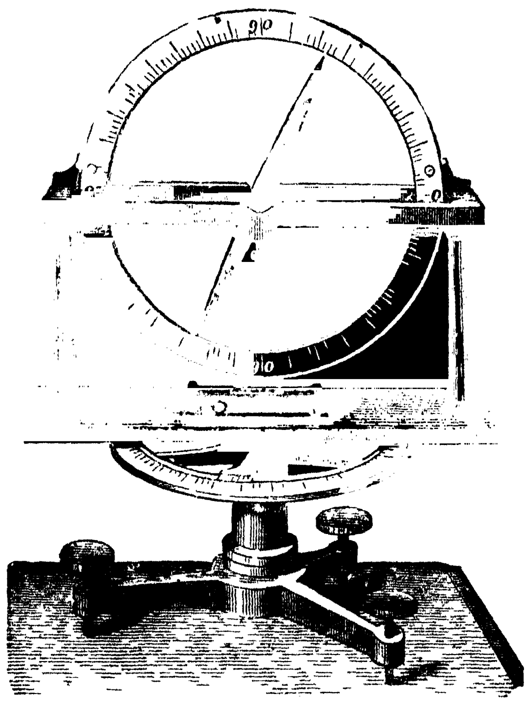

Fig 16. The Dipping Needle.

matical instrument maker of Wapping, but in 1600, Dr. William Gilbert of Colchester, physician to Queen Elizabeth, and afterwards to King James I., had, in his book "De Magnete," made out an elaborate list of the different materials which have in any marked way the electric peculiarity of attracting light substances.

To Otto von Guericke belongs the credit of having, in 1647, contrived the first Electric Machine, in the primitive form of a ball of sulphur, for which Sir Isaac Newton substituted, in 1705, a globe of glass—his being the earliest known adaptation of glass to the purposes of electric excitation.

Robert Boyle, towards the close of the seventeenth century, and Francis Hawksbee at the beginning of the eighteenth, it should next be added, materially advanced the science by the aid of their experiments. It was a less conspicuous electrician than either, however, who, in 1708, threw out a suggestion which, forty-four years later on, was magnificently developed on the other side of the Atlantic. This was Dr. Wall, who, in the year just named—as may be seen on turning to the "Philosophical Transactions" under that date—upon eliciting electricity from amber by friction, and upon observing thereupon the all but simultaneous spark and crackling detonation it provoked, compared them, in so many words, to a miniature outbreak of thunder and lightning!

Stephen Gray, another daring advancer of electric science, going beyond Wall's metaphor, plainly asserted about twenty years afterwards (these are the very terms in which his prescient thought is expressed), that electricity "seems to be of the same nature with thunder and lightning." The courageous conjecture thus put forth, Franklin, by a memorable experiment,

Fig. 17.—Franklin's Experiment.

adventured upon during a thunderstorm in the June of 1752, had the delight of proving to demonstration. Having put two light laths of cedar together in the form of a cross, and having covered them with a thin silk-handkerchief stretched tautly upon the framework, he, upon the first opportunity that presented itself, flew his kite adroitly into the midst of a thundercloud. Before sending it aloft upon its mission, however, he had carefully fixed upon its uppermost extremity a sharply-pointed spike of iron, and, upon having run out the twine sufficiently, fastened to it—the twine—at a point a little above where it was held in his grasp, a silk ribbon, from which a key was pendant. Under these conditions, as the storm darkened, he noticed first of all, here and there, minute shreds or gossamer particles of the string bristling out; and next, upon approaching the key with a knuckle of his disengaged hand, saw and heard that an electric spark was elicited. From that moment, the identity of lightning and electricity was no longer merely matter of conjecture. A toy in the hands of a philosopher had proved it to demonstration.

Meanwhile, not very long before this, other experimentalists in Europe had been notably advancing by their discoveries the hitherto scanty knowledge acquired of electric phenomena. Stephen Gray, already mentioned, for example, had shown that the human body is a ready conductor of electricity; and, further than this, he had demonstrated, by means of a packthread 880 feet long, supported by silken loops, that the electric fluid acts at a distance! Professor Boze of Wittenberg, with the primitive device of a tin tube held by an attendant, who stood the while upon a slab of rosin, had succeeded in furnishing the electrician with what was thenceforth known as the prime conductor. Besides this, Dr. John Theophilus Desaguliers had drawn, for the first time, the important distinction ever since recognised as existing between electrics and non-electrics, the latter, as he showed, being conductors, whereas the former have no power whatever of conduction.

Gradually, by this time, there had been growing up, in the laboratory of a series of experimentalists, a distinct machine for the production and manifestation of electricity. Towards its construction, those already named had one after another more or less contributed. Professor John Henry Winkler of Leipsic, towards the middle of the eighteenth century, substituted a cushion for the hand which, until then, had been applied to the revolving globe for the purpose of electric excitation. And, as the crowning achievement of all, in the fabrication of the original electric machine, a Benedictine monk from Scotland—Professor Gordon of Erfurt—first employed, as the generator of electricity, in place of a rotating ball, a glass cylinder, which a bow and cord set in rapid revolution.

Now-a-days, the machine used for the production of frictional electricity is either a circular plate of glass, or an ample glass cylinder, carefully insulated by being placed upon glass supports, so that the electric fluid generated by whichever piece of mechanism was set in motion might—not pass off, but be stored up in it.

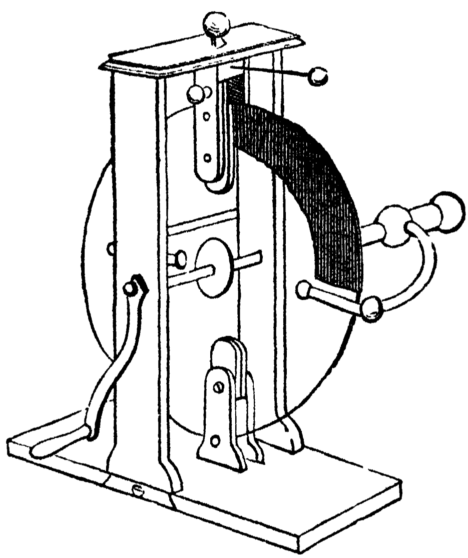

Fig. 18. · Plate Electric Machine.

An illustration of either being sufficient to explain the operation of both, the diagram upon the opposite page will make clear at a glance the appearance of one of the cylindric machines for the production of electricity.

Apart from the machine by which the electric fluid was thus frictionally generated, a contrivance was hit upon in 1745, by the help of which it could be collected together and stored up in abundance. This, from the receptacle employed, and from the place in which the arrangement was first completed, has ever since gone by the name of the Leyden jar. Three independent claimants for the credit of its invention were—a monk

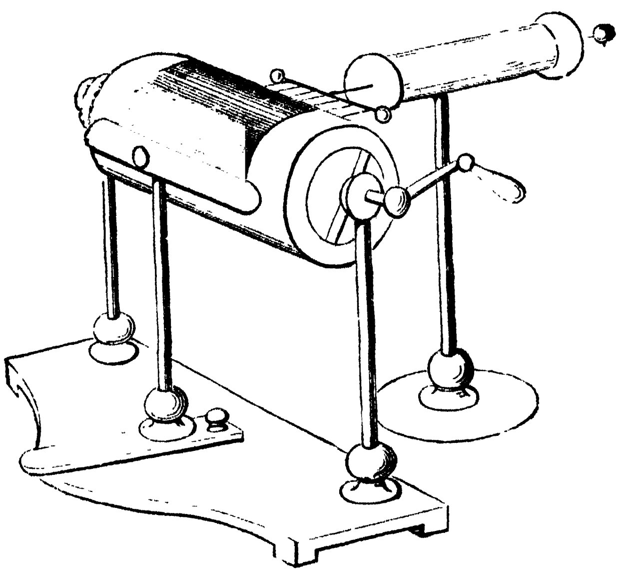

Fig. 19.—A Cylinder Electric Machine.

named Kleist, an electrician known as Cunœus, and one of the learned chiefs of the university of Leyden, Professor Muschenbroek. Before explaining by a word or two this simple but effective apparatus, it may be as well to realize the fact that by electrified bodies two distinct classes of phenomena are represented. There is that, for example, which results from the accumulation of electricity upon the surfaces of bodies, and which is expressed by the phrase of electricity of tension. Such, for instance, are the ordinary electric machine and its prime conductor. Anything thus electrified affects all surrounding objects which are thrown by it into a polar electric condition by what is called induction. Electricity thus stored up has a tendency either to escape gradually from points in themselves hardly appreciable, or by direct contact to pass off in sparks through the air with a detonation. A storm of thunder and lightning is generally instanced as about the sublimest illustration that could be adduced of this particular state or condition of electricity. As for the other class of electric phenomena, they are those of electricity in motion—considerable quantities of the electric fluid passing in these instances through a conducting medium without anything apparently happening.

With regard to the former class, that of electric tension, the spark is supposed to be the union of the two electric fluids, the vitreous and the resinous. Here, however, is the outline of a Leyden jar—the very name of which is like an electric pun.

This ordinary receptacle for the storing up of electricity, is a thin glass jar or bottle coated both inside and outside, to within three or four inches of its rim or mouth, with some conducting substance; the material generally employed for the purpose being tinfoil. Projecting perpendicularly upwards from the bottom of the inside of the jar to a few inches above the centre of its aperture, is a metallic rod surmounted by a brass ball, which consequently communicates thus directly with the inner coating. A Leyden jar is readily charged with electricity by the application of its brass ball to the prime conductor of an electric machine, the outer

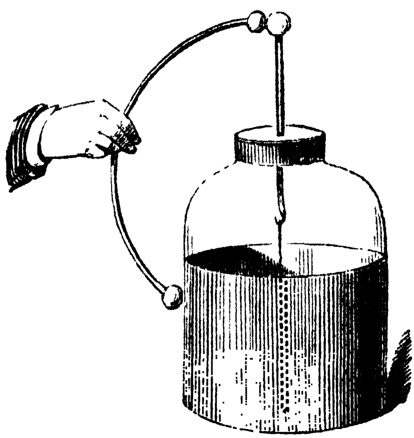

Fig. 20.—A Leyden Jar.

coating communicating with the ground through the hand of the person holding it—whereupon, the cylinder being set in motion, positive electricity is imparted to the interior of the jar, and negative to its exterior. Supposing the receptacle to be in this manner duly charged, upon making a communication by means of a conductor, between the inner and outer coatings, the two electricities are, with the production of a dazzling spark, annihilated; and, in the event of the experimentalist's body being made part of the circuit, he becomes aware of the passing of the electricity by an intolerable sensation known as an electric shock. Several jars being so arranged that their interior and exterior coatings are all of them separately connected, constitutes that powerful agent for the imparting of the fluid with accumulated force, called the electric battery.

Stephen Gray's transmission of electricity through upwards of 800 feet of packthread in the early part of the eighteenth century, already referred to, was followed up, in 1747-'48, by Sir William Watson's startling experiments, first in the heart of the metropolis, and afterwards in its immediate neighbourhood. In the earlier of these, he contrived to fire the electric spark through an insulated wire trailed across the Thames by the side of the bridge between Lambeth and Westminster; and in the later one he proved to demonstration at Shooter's Hill, that through a length of 12,276 feet of wire, electricity was instantaneously transmissible. Emulating this skilled electrician in the same year on the other side of the Atlantic, Dr. Franklin, after the very same fashion, sent the electric fluid across the Schuylkill at Philadelphia; while in the following year, 1749, De Luc did the like, no less effectively, across the waters of the lake of Geneva.

Addison, eight-and-thirty years before this,—during the last thirty years of which interval his mortal remains had been lying in Westminster Abbey—had, on the 6th of December, 1711, in one of the most charming of his essays, related in No. 241 of the *Spectator*, an apologue, which he evidently regarded as the wildest and most fantastic of day-dreams.

Borrowing it, with all gracious acknowledgment, at the time, from a learned Jesuit of Rome, one Famiano Strada, who had died there in the Eternal City on the 6th of September, 1649, Addison had translated it from the elegant Latin of the original, the "Prolusiones Academicæ," into as elegant English of his own. "Strada," he there relates, "gives an account in his 'Prolusiones' (vol. ii. p. 6), of a chimerical correspondence between two friends, by the help of a certain loadstone which had such virtue in it that if it touched two several needles, when one of the needles so touched began to move, the other, though at never so great a distance, moved at the same time, and in the same manner." Further than this Addison adds as the interpreter of Strada, "He tells us that the two friends, being each of them possessed of one of these needles, made a kind of dial plate, inscribing it with the four-and-twenty letters of the alphabet, in the same manner as the hours of the day are marked upon the ordinary dial-plate." How wonderfully exact as unconscious prognostics of what was going to happen two centuries afterwards, these imaginings of the Jesuit father, Famiano Strada were, as innocently interpreted for the amusement of after times by the great English essayist, the sequel in a double sense will serve to demonstrate.

"They then fixed one of the needles," continues Strada, speaking through the lips of Addison, "on each of these plates, in such a manner that it could move round without impediment, so as to touch any of the four-and-twenty letters." Each armed with this magical contrivance, it is added, that—"Upon their separating from one another into distant countries, they agreed to withdraw themselves punctually into their closets at a certain hour of the day, and to converse with one another by means of their invention." What follows is like an anticipative record of what several generations afterwards actually came to pass as a matter of ordinary occurrence. "Accordingly," we read, "when they were some hundred miles asunder, each of them shut himself up in his closet at the time appointed, and immediately cast his eye upon his dial-plate." Strada, through Addison, here enters into particulars, "If he had a mind to write anything to his friend, he directed his needle to any letters that formed the words which he had occasion for, making a little pause at the end of every word and sentence to avoid confusion." What follows? "The friend in the meanwhile saw his own sympathetic needle moving of itself to every letter which that of his correspondent pointed at." In the next passage it is difficult to believe that we are reading what was originally penned nearly two centuries and a half ago, and not, what it might have been thought rather, could only have been written but yesterday, as a description of comparatively recent achievements. "By this means," quoth Strada, "they talked together across a whole continent, and conveyed their thoughts to one another in an instant over cities or mountains, seas or deserts."

Addison, then, going on to speak in his own person nearly a hundred and eighty years ago, observes, "If M. Scudery, or any other writer of romance had introduced a necromancer; who is generally in the train of a knight-errant, making a present to two lovers of a couple of those above-mentioned needles, the reader would not have been a little pleased to have seen them corresponding with one another when they are guarded by spies and watches, and separated by castles and adventures." And then, with a touch of playful irony that shows more clearly than anything else could have done, how the writer toyed with a fancy which he regarded at the best as one but of the lightest moment, the humorist added, "In the meanwhile, if ever this invention should be revived (!) or put in practice, I would propose that upon the lover's dial-plate there should be written not only the four-and-twenty letters but several entire words which have always a place in passionate epistles"—thereby, as he remarks, with the zest of one who appreciated the value of comprehensive symbols, enabling these remote correspondents to express their most useful and frequently employed words by a single touch of the needle.

What was thus imagined by Strada and descanted upon serio-comically by Addison as the merest phantasy, was first seriously described as a thing actually capable of accomplishment about the middle of the last century by a contributor to the "Scots Magazine." Writing to that periodical under date, "Renfrew, 1st February, 1753," a correspondent signing himself "C. M." (supposed by Sir David Brewster to have been a Greenock man named Charles Morrison, but by others said to have been one named Charles Marshall,) gravely proposed, with scientific explanatory details that showed clearly enough that he was thoroughly in earnest, that two distant places might be readily brought into direct communication by means of as many electric wires as there are letters in the alphabet, messages being discharged through these wires, according to his plan, by what "C. M." termed an electric gun-barrel. As for the insulation of the four-and-twenty wires, that, he maintained, could be readily secured by coating them with jewellers' cement (!), while his suggested means of intercommunication were twofold, namely, either by the ringing of electrified bells, or by the attracting to one or another of the four-and-twenty wire-ends, of a paper marked with its respective letter.

Six months after this singular epistle had made its appearance, Professor George Richmann, while attempting at St. Petersburg to repeat Franklin's experiment in the midst of a terrific thunderstorm, was, on the 6th August, 1753, killed by the lightning. Whether in play or in earnest, experimental electricians were steadily advancing, by this time, from year to year, the development of the science they were bent upon cultivating. John Canton, the discoverer of what is termed electrification by induction, demonstrated that the atmosphere of an apartment could, according to option, be electrified either positively or negatively, and that its condition in either state could for a long period be sustained. Giovanni Beccaria, again, contrived to render the electric flash visible in water by bringing two wires immersed in it near each other. While Robert Symmer in 1759, as may be seen by turning to the "Philosophical Transactions" of that year, describes in the most amusing way the comical experiments indulged in by him on his chancing to observe that when he drew off his silk or worsted stockings, there were visible and audible in his darkened bed-room a great sparkling and crackling! Remarking that even when drawn off they expanded, as if a leg were still inside each, and that they had for each other certain electric attractions and repulsions! Holding two black silk stockings in one hand, and two white ones in the other, all of which he had just been wearing, and allowing them to approach each other: "the repulsion," he writes, "of those of the same colour, and the attraction of those of different colours throws them into an agitation that is not unentertaining," making them catch each at that of its opposite colour at a greater distance than could have been expected.

Sometimes the oddest freaks have been indulged in by experimenting electricians, as when Franklin at a picnic in 1748 killed a turkey by an electric spark, and roasted it by an electric jack before a fire kindled by an electric bottle. And not infrequently results of the last importance, it should be added, came from these apparently frivolous eccentricities. As when, in 1762, Professor Johann Sulzer of Berlin idly put into his mouth, like a couple of lozenges, a little disc of zinc and another of copper. Happening to have the zinc above and the copper below the tongue, he noticed that when the edges were brought together at the tip, he experienced there a curious itching sensation and a taste like sulphate of iron. Reversing the position of the two, having the copper above and the zinc below the tongue, he then felt and tasted something so peculiar as the result that its character baffled description. Subsequent investigation demonstrated that in each case the effect was electric, the one being an acid flavour produced by positive electricity and the other an alkaline flavour produced by negative electricity. In this curious and seemingly valueless little experiment, was latent the germ of the discovery of a most important manifestation of electricity, which came to be known, from its elucidator, as the galvanic current. What the source of that current is, a very few words will suffice to explain. Whenever a piece of metal is partly immersed in a liquid, it becomes, so to speak, polarised — what is above being positive, and what is below negative: experience showing, later on, that the strongest polarization is that set up by zinc and tin when placed in solutions of nitric or sulphuric acid—zinc and tin thus partially immersed being recognizable, now, as the most potent and reliable of all electromotors. Sulzer's odd experiment, however, in the mere mention of it has tempted me, slightly to anticipate—what has just been said having more direct application to those two notable outcomes of it, which will be referred to in due order almost immediately—the voltaic pile and the galvanic battery.

Shortly before the discovery of either, Charles de Coulomb, in 1785, constructed his exquisitely delicate instrument known as the Torsion Balance, by means of which electric force can at all times with mathematical precision be most accurately measured. A couple of years after this, when Arthur Young, then Secretary to the Board of Agriculture, was in the midst of that delightful tour of his on the other side of the Channel,

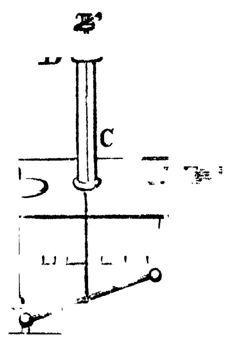

Fig 21 —Coulomb's Torsion Balance.
A B, a cubical case of plate glass C D, glass tube.

in which he may be said to have formally taken stock of France immediately before the outburst of the great Revolution, he records under date the 16th of October, 1787, the mingled pleasure and astonishment with which he had witnessed that evening in Paris the transmission of intelligence through a wire by Monsieur Lomond. According to the English traveller's account of what he calls this "remarkable discovery," an account published by him in 1794 (vol. i. p. 79): — Having himself written down certain words on a slip of paper which he handed to M. Lomond, the latter taking it with him into a room apart, turned a machine enclosed in a cylindrical case, at the top of which, in the shape of a dainty little pith-ball, was an electrometer. Far removed from this place, but connected with it by a wire which ended, in a distant apartment, with a precisely similar apparatus, the electrician's wife, by remarking the motions of the pith-ball confronting her, was enabled to write down the words they indicated, Having stated, with evident wonderment, what he himself had thus witnessed, Arthur Young closes his record of it with the remark that, "Whatever the use may be the invention is beautiful."

Electroscopes of various kinds have since then been constructed, some of them of marvellous ingenuity, and those of a subtler nature of exquisite sensitiveness. In every one of them they are dependent upon the rudimentary truth that bodies similarly electrified have for each other a mutual repulsion. Pendent pith-balls, hung side by side from a common metallic support, repel each other when charged with electricity. Other electroscopes of gold leaf, now single, now double, have been contrived of exceeding delicacy, very notable among these being Bennet's and, even yet more remarkably, Bohnenberger's. According to the movements caused by the electric current, whether in the pith-balls or in the particles of gold leaf, it will be instantly comprehensible, of course, how an alphabet of pulsations admits of being readily arranged.

Accident in 1790 suddenly opened up a new and

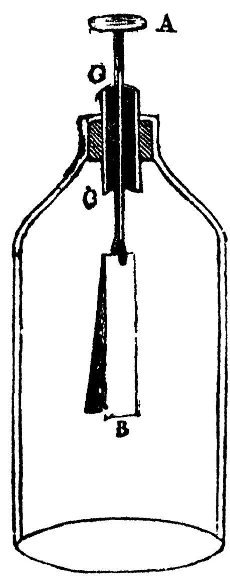

Fig. 22.—Gold-leaf Electroscope.

most important field of enquiry to the electricians of Europe. It arose thus :—Madame Galvani, the wife of the Professor of Physics at the University of Bologna, being slightly indisposed, was recommended by her physician to partake of some frog broth. Several frogs, in consequence of this prescription, having been skinned and washed preparatory to being cooked, were laid for a few moments, while the pot of water was getting ready, upon the table of Dr. Luigi Galvani's laboratory. As it happened, one of the professor's assistants was

Fig. 23.—Galvani's Experiment.

just then actively engaged in whirling round the cylinder of a large electric machine, making a series of experiments. While he was doing so, Madame Galvani observed with amazement that whenever he caused electric sparks to explode from the conductor, the tiny legs of the dead frogs twitched as though they had been still alive. Her husband's attention having been called by her to these remarkable movements, Luigi Galvani at once entered upon a series of searching investigations with a view to discover the cause of the phenomena. Among the tests applied by him, Galvani hung up one of the skinned frogs by a hook of copper wire upon the iron balustrade outside his window, immediately upon which he observed that its limbs were thrown into the liveliest convulsions. These he attributed, quite in error as it happened, to animal electricity. For, another Professor of Physics of that day, Alessandro Volta, of Pavia, hearing of what had taken place and of the conclusions at which his contemporary had arrived, threw out the suggestion in regard to what had come to pass, that the copper of the hook and the iron of the balustrade had been the real electromotors, the muscles of the frog probably acting as no more than a mere moist conductor between the two metals, thereby completing the circuit. Galvani's experiment had thus led Volta to the distinct opinion that the bringing into communication thus of two entirely different metals had been sufficient of itself to produce electricity!

Hitherto, electricians had only known of frictional electricity. Henceforth, they became just as familiarly aware of another kind of electric current, which has been ever since variously known as galvanic electricity, so called from the originator of the experiment, and as voltaic electricity, from the explainer of the phenomena.

Fig. 24.—Portrait of Volta.

How important this discovery was as a step towards the ultimate realization of the electric telegraph, will be understood at once when it has been remarked that the force of frictional electricity would have been quite inadequate for the transmission of intelligible signals through any great lengths of wire—from city to city, from one end of a country to the other, under oceans and across continents. For this purpose, even galvanic

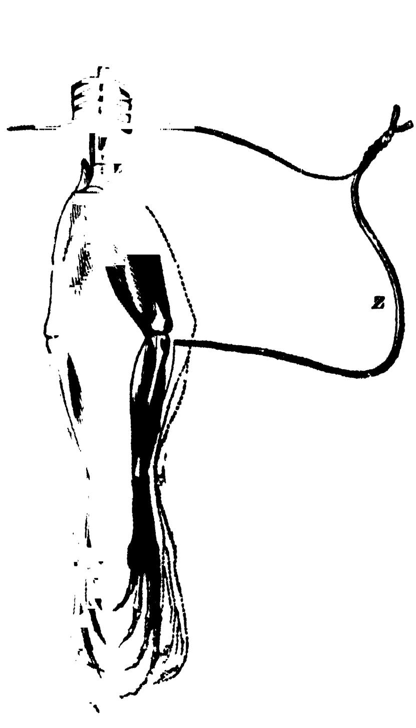

Fig 25.—Frog's Legs and Spine. c and z, copper and zinc wires.

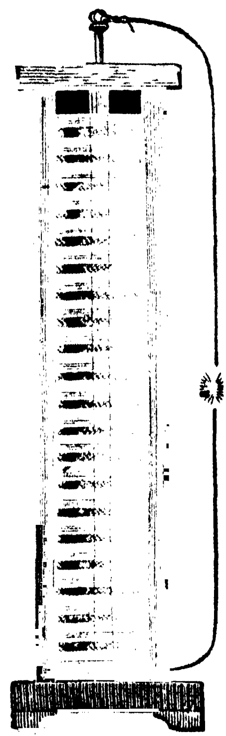

Fig. 26.—Voltaic Pile.

or voltaic electricity would have been altogether insufficient, but for the two-fold contrivance hit upon by Volta for the concentration, as it were, into a focus, of its aggregated force, either in the voltaic pile, or in the galvanic battery. In the instance of the former, an electric current of high tension is obtained by piling up on one another, upon a foundation of plate-glass, of a series of discs—usually twelve of these groups of three, zinc, cloth, and copper, zinc, cloth, and copper, in invariable succession. Moistening the cloth with brine or with diluted sulphuric acid, and then connecting the uppermost zinc plate with the lowermost copper one, an electric current of considerable power is obtainable. As for the galvanic battery, which is otherwise poetically

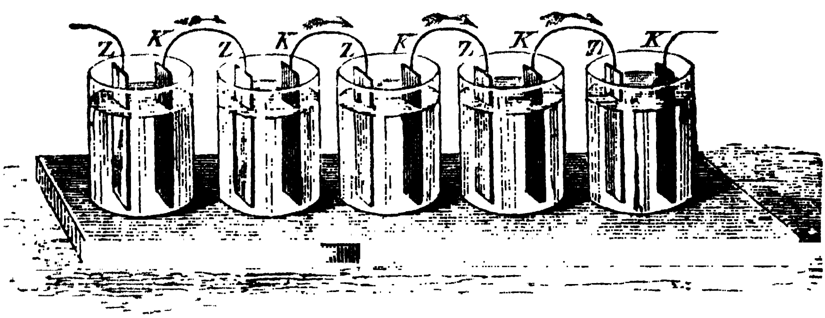

Fig. 27.—The Crown of Cups.

entitled Volta's Crown of Cups, it consists of a series of metallic plates, ranged in pairs, in a wooden trough, which is portioned out in compartments. Premising that a galvanic element, as it is called, or battery cell, is such an arrangement as a plate of zinc and a plate of copper partially immersed in diluted sulphuric acid, I would add here that several such cells, usually again a dozen in number, go to the making up of a galvanic battery. A water-tight wooden trough, divided into compartments, each of which is first filled with pure white sand, and afterwards with the watery acid already mentioned, is what ought to be first prepared in the construction of a galvanic battery. Having then got ready as many pairs of zinc and copper plates as are intended to be employed—each linked by a copper band to its companion—these are so arranged that every brace bestrides one of the partitions. Wherever zinc, besides, is one of the two metals used in the making up of a galvanic battery, seeing that from its very nature it must otherwise be eaten away very rapidly by the sulphuric acid, it is, as a precautionary measure, prepared for its sour bath by being twice dipped in a bath of quicksilver. Such, in a few words, is the ordinary galvanic battery. But others there are of a higher class, the cells of which are distinct jars or pots, instead of being merely water-tight wooden compartments.

Before the first ten years of the new century had run out, Herr Samuel von Sœmmering had, on the 29th of August, 1809, exhibited at Munich an electro-telegraphic arrangement so effective in its way that the only bar to its practical adoption as affording a means of rapid communication between places widely apart from each other, was the exceeding costliness involved in its construction, from its number of wires, a separate one being required for every letter in the alphabet. A precisely similar objection, namely, as to costliness, alone stood in the way also of the no-less ingenious electric telegraph, contrived with a line of wire eight miles long, in 1816, by Sir Francis Ronalds, of Hammersmith, who, as one of the earliest of the great pioneers of the electric telegraph, was, as recently as in 1870, deservedly knighted, dying, by the way, three years afterwards at the age of eighty-five. According to his admirably clever arrangement, two clocks, at the opposite extremities of the line, beating isochronally, that is, stroke by stroke together, had each a dial on the second hand arbour, marked round the margin of it with the letters of the alphabet, and capable of being moved round at option, so that one letter alone at a time could be revealed through an aperture in the main dial.

At length, just three years after Sir Francis Ronalds' electric telegraph was completed at Hammersmith, a great truth was revealed which, for the first time, brought into play with each other the electric current and the magnetic needle. How directly and visibly the former acts upon the latter was, as the reward of many long and profound researches, first revealed in 1819 to Professor Hans Christian Œrsted of Copenhagen. Thenceforth the ambition which opened up before the electricians of both hemispheres, was one leading them on to the improvement and completion not of the electric telegraph, but of the electro-magnetic telegraph.

Fig. 28.—Œrsted's Discovery.

During the year just named, Œrsted announced, at a private lecture to some of his more advanced students, that voltaic electricity in passing through a metallic wire visibly affected a magnet in its neighbourhood. During the July of the following year, he demonstrated

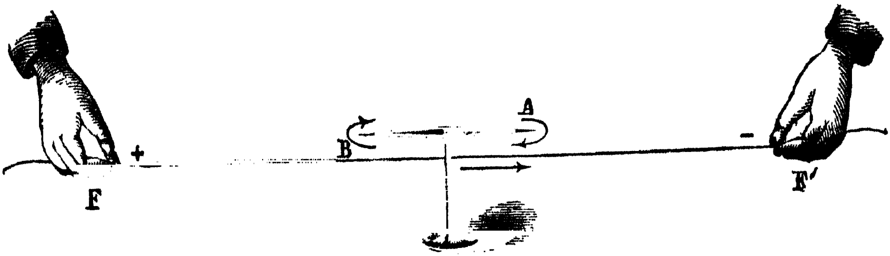

Fig 29.—Magnetic Needle above the Electric Wire.

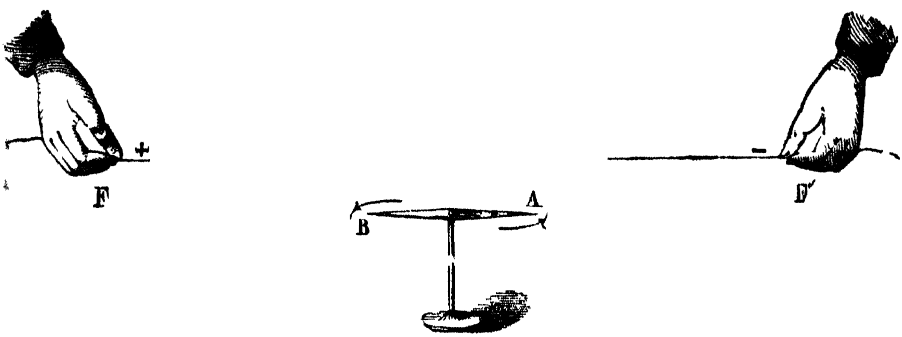

Fig. 30.—Magnetic Needle below the Electric Wire.

this before them by a series of astounding experiments. Having so arranged a metallic wire that it was placed horizontally exactly in the magnetic meridian, he showed that, on his passing positive electricity through it from north to south, if he held a compass needle above it, its northern extremity moved to the west, and if under it, to the east; and, further than this, that if he held it on the east side of the conductor, the north end of the needle was raised, and if on the west, it was depressed. Announcing his discovery in a Latin tract

Fig. 31.—Portrait of Ampère.

before the month was out, Œrsted may be said to have fairly electrified the scientific world by his revelation.

André Ampère, a French mathematician who has been since dubbed, hardly with extravagance, the

Newton of Electricity, gave the nearest approach to an explanation of any yet attempted as to how it is that the magnet thus endeavours to place itself at right angles to the current of electricity. An additional flood of light was thrown upon this mysterious antagonism on the part of two of the great forces of nature, in the January of 1821, by Professor Michael Faraday's announcement at the Royal Institution of his wonderful discovery of electro-magnetic rotation. In the course of his marvellous experiments, he showed how a magnet floating in mercury can be made to revolve continuously round a central conducting wire, and, on the other hand, how a conductor may be compelled, so long as the electricity is flowing, to rotate round a fixed magnet. Even beyond all this, he showed how a magnet may be compelled to twirl with great rapidity upon its own axis, so long as merely one half of its length is traversed by an electric current.

Ten years after this—in 1831—Faraday won to himself additional glory as an electrician by discovering magneto-electricity (which is the converse of Œrsted's electro-magnetism), and at the same time the wonderful fact of magnetic induction. By his experiments, demonstrative of the latter, he showed that—no less clearly than, as was already known, electricity had the power of affecting the magnet—a magnet had the capacity on its side of exciting electric action.

The fundamental truth, indeed, upon which the whole system of the electro-magnetic telegraph is built up, may be expressed in the statement, that when a current of voltaic electricity is passing through a metallic wire, there is simultaneously evolved at right angles to it a magnetic current, which rotates upon the conductor as upon its axis.

Whenever, therefore, a common magnetic needle, capable of turning horizontally upon a pivot, is placed near a wire conveying the voltaic current, the magnet is at once by necessity deflected from its meridian, the tendency of the needle being, in fact, to place itself at right angles to the conductor. Out of a recognition of this elementary truth, indeed, that the electric and magnetic forces deflect each other, have sprung up all the various forms of the galvanometer.

What has especially to be noted, so to speak, upon the very threshold, in regard to the electro-magnetic telegraph, as it came to be eventually arranged, is this, that the magnetic needle and the deflecting current, instead of being placed in relation to each other, as they were in all the preparatory experiments, horizontally, are invariably placed parallel to one another, vertically or perpendicularly.

A single needle and a five needle electro-magnetic telegraph were, in 1832, privately exhibited by Baron Schilling von Cronstadt to the Czar Alexander I. and to the Grand Duke, his brother, who afterwards succeeded him as the Czar Nicholas.

A couple of years after this, in 1834, one of the two men, Cooke and Wheatstone, who were chiefly instrumental in eventually placing at the command of the public at large the wonders of the electric telegraph—the latter of these two, world-famous, now, as Sir Charles Wheatstone—calculated to a nicety the velocity of the electric current, which, according to his estimate, on the double fluid theory was at the rate of 288,000 miles a second, and upon the single fluid theory 576,000 miles a second—its transit, otherwise to express the fact in a single word, being instantaneous! Another interval of two years having then elapsed, Wheatstone, in 1836, constructed an electro-magnetic apparatus by which, through four miles of wire, he was able with great precision to despatch as many as thirty signals.

It was in the following year, however, 1837, historically memorable as that of Her Majesty Queen Victoria's accession, that the true history of the electro-magnetic telegraph in its completed form may be said to have commenced. Upon the 12th of June, a patent was jointly taken out for a magnetic-needle telegraph by William Fothergill Cooke of Breeds Place, Hastings and Charles Wheatstone of Hanover Square, Middlesex According to the heading of the specification, it was for "improvements in giving signals and sounding alarums at distant places by means of electric currents transmitted through metallic circuits." Upon the night of the 25th June, 1837, a copper wire having been laid down between Euston Square and Camden Town—Mr. Cooke being at one end of the line and Professor Wheatstone at the other, each with his electro-magnetic apparatus—their joint invention was for the first time put seriously to the test.

Wheatstone has recorded with what emotion he witnessed its triumphant success. "Never," said he, "did I feel such a tumultuous sensation before as when all alone in the still room I heard the needles click; and as I spelled the words, I felt all the magnitude of the invention, now proved to be practical beyond all cavil and dispute." A little more than thirty-two years afterwards—Wheatstone in 1868, and Cooke in 1869—both the inventors were most justly awarded the honour of knighthood. For, if they were not, according to a popular fallacy which long prevailed in their regard, the actual originators of electro-magnetic telegraphy—its Contriver, in truth, as the account here given has already shewn, being a noun of multitude signifying many—Wheatstone and Cooke were beyond all doubt the first who upon a comparatively large scale, brought into practical operation for the benefit of the whole world, the wonders of the electric telegraph.

Five years previously, towards the close of 1832, Samuel Morse, an American artist of some repute, while he was crossing the Atlantic on his way back to the United States, conceived the idea which he, in the

Fig. 32.—Portrait of Morse

course of time, contrived most happily to realise, of constructing an electro-chemical telegraph. A model of his recording apparatus he had actually produced in 1835, but it was not until two years afterwards that the patent for his invention was taken out, during the same twelve-month in which was given to the world that of Cooke and Wheatstone. Not until 1844, however, was Morse enabled to bring his scheme into veritable working order; and, more than that, it was not until 1856 that he was enabled at last to put his system successfully to the test here in London.

During 1838, the first telegraphic wires for public service were laid down on the Great Western Railway, between Paddington and West Drayton. Trailed at the outset by the side of the line in an iron tube underground, they were afterwards for better insulation set up, in 1844, according to the plan which has ever since prevailed, on lofty poles to be out of harm's reach, poles seventeen feet high, and 500 feet apart, passing at the summit of each of these supports through an eyelet hole in a glazed earthenware insulator. Copper being dangerously tempting to purloiners, the line wires as a rule are of iron, painted with tar to prevent oxidation, sometimes, however, being covered with a thin film of zinc, or in other words galvanized. As originally projected, even in its simplest form, the electric telegraph, it was conceived, required, to complete the circuit between any two given places, the laying down or setting up of two wires, in one of which the electric current would go, and in the other of which it would return simultaneously. As early as in 1837, however, it was discovered that the second line wire was entirely superfluous, the earth itself completing the circuit between two stations, no matter how far they were removed from each other. To ensure the thoroughness of this earth connection, at each place a copper plate, an earth plate as it is called, is buried, attached to the end of the wire which is the channel of communication.

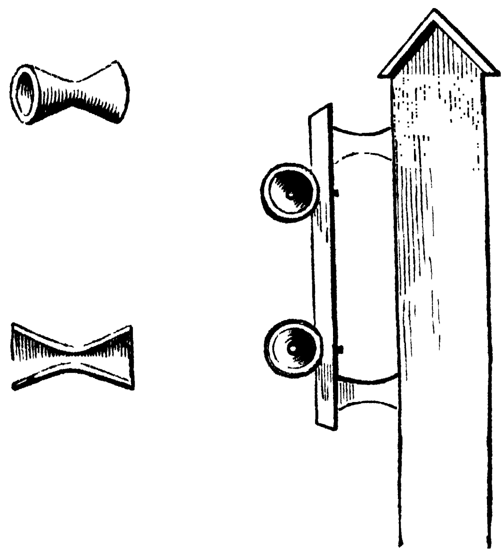

Fig. 33.—Telegraphic Post and Insulators.

It is curious to remember, now, that the galvanic telegraph, first brought into play at the close of 1838, by Cooke and Wheatstone, had a working apparatus at each end not larger than a common hat-box. Diminutive though it was in size, however, it was applied so effectively from the very beginning as a means of rapid intercommunication, that twenty-five miles of wire were in the following year, 1839, brought at once into use on the London and Birmingham Railway. And at each extremity of it, Strada's dream of 200 years before, marvellous to tell, was literally realized—the magnetic needle pointing in obedience to the touch of the distant sender of the message, to one or another of the four-and-twenty letters of the alphabet! By 1840, Wheatstone's dial instrument was regularly employed on the Blackwall Railway, and in the following year at Glasgow. By that time the same inventor had patented, in 1841, a still more amazing contrivance—one almost magical it seemed then—to wit, his alphabetical printing telegraph. When three years had run out, the first telegraphic line ever seen in America was opened between Washington and Baltimore. Eighty-eight miles of wire on the South-Western Railway, here at home, were by that time, in return for the use of it by Her Majesty's Government, bringing in £1,500 a year under that one item, into the hands of Cooke and Wheatstone.

At the close of the last day of 1844, a startling illustration was afforded by the Great Western line of the astounding velocity with which the electro-magnetic telegraph flew upon its errand. When the clock struck midnight on the 31st of December, the superintendent at Paddington signalled to his brother at Slough, that he wished him a happy new year, the answer immediately returned to this suggesting that surely the wish was premature, seeing that the new year at Slough had not yet commenced. Time itself, as measured out by the revolution of the earth upon its axis, had been outstripped by electricity.

Upon that very day, however, about the dawn of

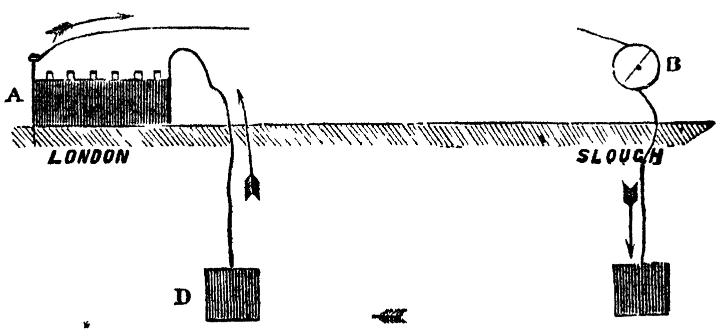

Fig. 34.—Earth Plates and Electric Circuit between Slough and London. A, battery. B, instrument. C and D, earth plates. Arrows show direction of electric current.

which there was this surprising discrepancy, that is upon the 1st of January, 1845, there was to come from Slough to Paddington, a yet more astonishing illustration of the wonders wrought by the electric telegraph. This was by the capture through its agency of Tawell the murderer! Immediately after that miscreant had poisoned his victim with prussic acid at Salt Hill, he so far succeeded in eluding his pursuers as to jump into the up-train at the Slough station, a few moments before its departure. A signal being made shortly afterwards, however, to the London terminus, to stop a certain first-class passenger dressed like a Quaker—there, coolly awaiting the assassin on the platform at Paddington, was a policeman in plain clothes, who, having seen his man descend from the carriage and enter an omnibus, quietly got up behind the latter vehicle, with a whispered word to the conductor! Perhaps the tracking down thus to his doom of this wretched criminal, realised more vividly to the public at large than anything else had yet done, the marvellous efficiency of the new and mysterious agency which had so very recently been placed at its command. More than the lifetime of a generation has since then elapsed, during which the wires of the electric telegraph have been spread in a wonderful network all over the globe—for all the world like the nervous system of modern civilization. Nothing whatever has proved capable of barring its progress. It has traversed the four continents from end to end. It has been trailed over the loftiest mountains, and along the profoundest depths of the ocean, linking together the old world and the new, and bringing England, so to say, within speaking distance of her remotest colonies.

Wheatstone, as far back as in 1840, sketched out plans for a projected submarine cable between Dover and Calais. Seven years after that, gutta-percha was suggested by Faraday as an efficient insulator, and in the same twelvemonth, 1847, John Brett, on behalf of his brother, Jacob Brett, the inventor and patentee, submitted unsuccessfully to Louis Philippe a new project for a sub-channel cable, which project was allowed by Louis Napoleon to have a fair trial at last, a year or two afterwards. That trial took place on the 28th of August, 1850, when the *Goliath* steam-vessel started from her moorings at Dover, paying out from her stern as she went a coil of telegraphic cable half an inch in diameter. By evening the English ship was off the French coast, the shore end of the gutta-percha cable with its copper core being run up at Cape Grisnez to the terminal station, in which it was eagerly welcomed. Messages were then at once exchanged between France and England. But the unprotected gutta-percha cable, with the single wire at its centre, having chanced, while it was settling into the sea-bottom, to cross a sharp ridge of rock, suddenly snapped asunder, the momentarily successful enterprise terminating, for that while at least, in complete failure.

Shortly afterwards, however, new arrangements upon a greatly enlarged scale having been entered into, for the carrying out of the baulked project, the revised plans were so energetically advanced that, by the September of 1851, England was securely brought into instantaneous communication with the European continent. The cable then sunk at the bottom of the channel between Dover and Calais, had at its heart four copper wires twisted together like the strands of a rope, each doubly enclosed in gutta-percha, all four being then surrounded by a soft tough case of tarred hempen yarn, which in its turn was guarded by a strong outer covering of ten iron wires closely lapped round all, at once spirally and longitudinally, the whole weighing seven tons per nautical mile.

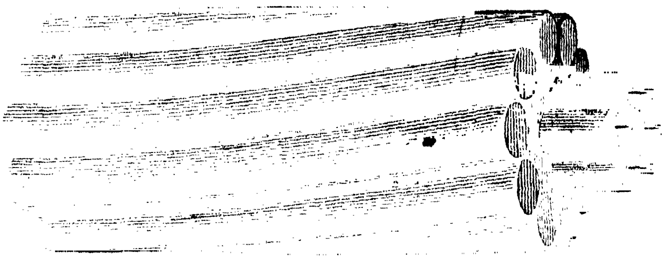

Fig. 35.—Cable between Dover and Calais.

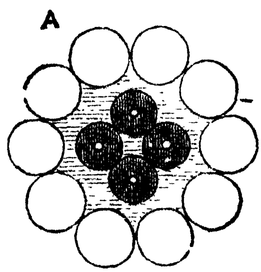

Fig. 36.—Section of Cable between Dover and Calais.

On the 13th of November, 1851, this first permanently laid electric cable, was, with great rejoicings in both countries, formally inaugurated. The opening and closing prices on the Paris Bourse were known within business hours on the Stock Exchange, and *vice versâ:* guns in honour of the event being fired from the opposite shores at Dover and Calais by electric communication.

A couple of years after this, in 1853, duplex telegraphy was discovered—Dr. Gintl, an Austrian electrician, demonstrating that two messages could be sent at the same instant along a single wire in opposite directions—Herr Stark of Vienna, yet more, showing a couple of years later in 1855, that two messages could just as easily be despatched simultaneously in the same direction. The apparatus for the better working of this subtle branch of telegraphy, it should here be added, was perfected about the same time by Stearns, an American.

Direct communication by electric cable was established, by the way, between Dover and Ostend, on the 6th of May, 1853, the seventy intervening miles being traversed by a semi-metallic rope, weighing 500 tons altogether. About the same time a much lighter cable was laid down between Portpatrick and Donaghadee; while in the year 1854, Holyhead and Howth were similarly connected. In the following November, Paris and Bastia were in like manner linked together. By the May of 1858, the lines of submarine cable and overland wire had been so lengthened out, that London and Constantinople were brought into direct intercommunication. A twelvemonth afterwards Aden and Suez for the first time thus spoke to each other; on the 28th of September, 1861, Malta and Alexandria; and on the 1st of March, 1865, England and Bombay.

Meanwhile there had been rapidly growing up in

London—ever since, in 1857, the Messrs. Waterlow in this way united their city premises with their west-end establishment—that overhouse system of trailing the telegraphic wires which was first begun at Paris, and which has since then so largely increased and multiplied in the English metropolis, that the latter has long since come to look for all the world like a city of Lilliput, in which a Brobdingnagian spider has been spinning its web in all directions. Nor can this be regarded as in any way surprising, when it is borne in mind, as an indication of how wonderfully swift was the spread of the electro-magnetic telegraph system from the commencement, that, as far back as the July of 1862, there were already at work 15,000 miles of wire in Great Britain alone, 80,000 on the European continent, and 48,000 in America, making an aggregate, when swelled by the returns of a very few other quarters, of fully 150,000 miles of wire even then set apart for the purposes of electric telegraphy.

Six years after the last-mentioned date, this form of industry had in fact assumed to itself such magnitude within the compass of the United Kingdom—there being by that time in Great Britain alone 20,000 miles of line, and nearly 110,000 miles of wire, with 8,000 instruments, giving employment to 10,000 individuals—that upon the 31st of July, 1868, the Telegraph Act was passed into law by Imperial Parliament. By it the Postmaster-General was empowered to purchase, as he eventually did, the whole of the existing telegraphs, Mr. Frank Ives Scudamore, secretary of the Post-Office, being appointed, in the January of 1872, the Director of the new organization. During the course of the ensuing month, February, 1872, the system of Postal Telegraphy began, and with so marked an effect in furthering its expansion, that messages had risen by 1875 from 6,000,000 to 20,000,000, the gross receipts having risen in 1880 to £1,471,000 sterling. As indicating yet further the rapid growth since then of this department of the public service, it may be added that the revenue derived from Telegrams alone in 1888, amounted to upwards of £1,959,000.

Calling the reader's attention now to the Electric Telegraph, not as an institution, but as an instrument, I would here remark that the three all-essential qualities of a line of wire are its conducting power, its insulation, and what is called its electro-static capacity, meaning—that last-mentioned—its capacity to produce and discharge in rapid sequence, stationary supplies of electricity. Magneto-Electric Telegraphs there are of course of various forms of construction, but one and all of them are alike in this, that they have two grand divisions—the sending apparatus and the indicator. A sending instrument involves, as a matter of course, an electric machine of some description, or, technically speaking, an electromotor. For this purpose a frictional machine would have been practically inoperative, it being altogether too feeble to admit of its systematically signalling electrically. But for the discovery of galvanism, and the twofold invention afterwards of the voltaic pile and the galvanic battery, the Electric Telegraph, as the world now knows it, could never have sprung into existence—the galvanic battery and the voltaic pile still remaining to this day by general consent the most thoroughly efficient of all electromotors.

Thanks to Faraday's magnificent discovery already referred to of electro-magnetic induction, an entirely different kind of electromotor was employed, which was applied with signal success in bringing about the grandest of all telegraphic achievements, that of signalling at the rate of ten or twelve words a minute, through the Atlantic cable, between Ireland and Newfoundland. As far back as in the June of 1845, a formal proposition was made to the British government by the Messrs. John and Jacob Brett, for the laying down of a sub-oceanic electric cable between Europe and America. Almost disdainfully set aside at that time as a thing impracticable, this very plan was some twelve years afterwards attempted to be carried out by a mercantile company, with the joint approval of the British and American governments.

A length of some 2,500 miles of cable having, in the early part of 1857, been manufactured, in the August of that year, the laying of it down began at Valentia in Ireland. The wire employed in its construction was long enough, it has been calculated, not only to have reached as far as from the earth to the moon, but to have been capable of lapping several times besides round both planet and satellite. When about a sixth of the whole cable had been paid out from the stern of the *Niagara* as she steamed westwards across the Atlantic, the rope, to the dismay of all on board, abruptly parted. A length of some 55 miles, a few months afterwards, was recovered in fairly good condition, but the rest of what had been thus ineffectually submerged, lies there still in the profound tranquillity of the great ocean depths to which it had been lowered.

As if deriving encouragement from their first experience, the promoters of the enterprise had, by the May of 1858, got in readiness some 3,000 British statute-miles of cable, half of it coiled on board H.M.S. *Agamemnon*, and the other half on board the U.S. *Niagara*, two of the grandest line-of-battle ships then afloat. These vessels having made an experimental cruise in the Bay of Biscay, where they put to the test satisfactorily all their various appliances, started on the 10th of June for the middle of the Atlantic, as their appointed place of rendezvous. Thence—having, in three abortive attempts, lost some 500 miles of cable — they returned before the 13th of July to Queenstown. Before that month was out, however, they were again at their mid-ocean place of meeting, where, in fact, on the 29th of July, they joined the two ends of the cable securely together, and began paying it out in 2,400 fathoms of water, the *Niagara* pursuing its way westwards, and the *Agamemnon* retracing its path eastwards, to their respective destinations. By the 5th of August both vessels parted with the cable, leaving its opposite extremities on shore at either side of the Atlantic. The European terminus was in *Trinity Bay* in the harbour of Valentia—the American terminus in Bull's Arm Bay, one of the branches of *Trinity Bay* in Newfoundland. Cordial messages of congratulation were—on the day following the completion of the batteries—interchanged between the Queen and President Buchanan.

Exactly 1670 miles marked the length of this cable from shore to shore, at the core of it being seven copper strands (six round one) forming a wire rope thrice coated with gutta-percha, swathed about in its turn with tar-saturated hemp, and yet further coiled round externally with eighteen strands of iron wire—the whole having a breaking strain of 3 tons 5 cwts. After three months more or less satisfactory communication to and fro between Europe and America at length on the 20th of October, there were unmistakable signs of faltering in the cable, until—abruptly in the middle of a message—its power ceased altogether. Bitter must have been the disappointment experienced at this untoward result by Mr. Cyrus Field, an ex-merchant of New York, its chief promoter, £375,000 having been only too literally sunk in the enterprise.

Seven years afterwards, however, thanks principally to his untiring energy, another company was formed, and another coil of rope manufactured, a coil so enormous, that if brought together, it would have nearly filled from floor to roof the interior of Astley's amphitheatre. Happily, in Brunel's gigantic steamship, the *Great Eastern*—the mightiest vessel, as has been said, ever constructed "Since Noah's ark floated on the waters of the Deluge"—the bearer and payer-out of a vaster and more ponderous cable than had ever before been fabricated was then in existence, and at the command of the promoters of the enterprise. On board of her, in three tanks, 2,230 miles of this huge and weighty cable, which had a breaking strain of fully seven tons altogether, were stowed away. Starting this time, not from Valentia harbour, but six miles thence, from Foilhommerum Bay in Ireland, the conductors of the enterprise on Sunday the 23rd of July, 1865, went westwards across the Atlantic towards their intended destination in Newfoundland. Twice on their way their progress was interrupted by reason of some villain having treacherously stabbed through the gutta-percha with a morsel of wire. Otherwise than when these foul wounds (each time carefully healed) were inflicted, the insulation of the cable was so perfect that whenever the *Great Eastern* rolled in mid-ocean,

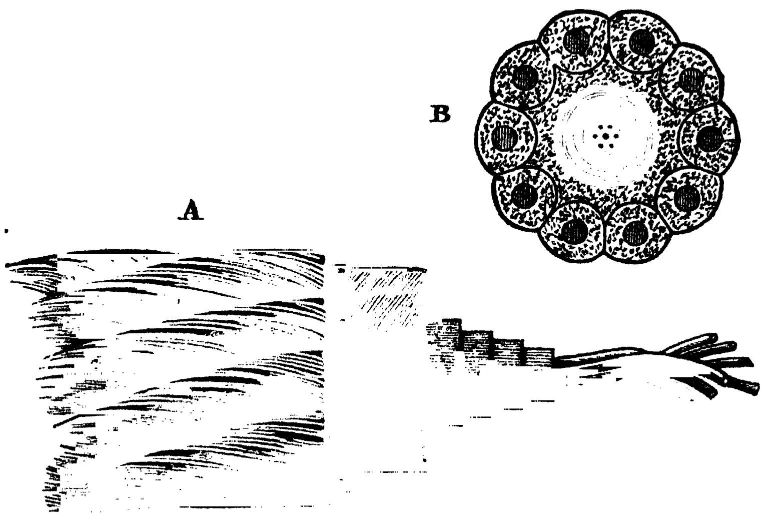

Fig. 37.—Atlantic Cable of 1866 and Section of it.

the fact of her doing so was unmistakably indicated at Foilhommerum, by the oscillations of the mirror galvanometer. Everything having so far prospered, when 1,200 miles had been satisfactorily run out, and when the *Great Eastern* was no more than 600 miles from her place of destination in the New World—suddenly, on the 2nd of August, the cable snapped! Although at the precise spot where the catastrophe occurred the Atlantic was two and a half miles deep, the lost cable was thrice actually grappled, further serious attempts at its recovery having then to be abandoned until the following twelvemonth.

Where the end had gone down, in lat. 51° 27′ 30″ N.; long. 38° 50′ W., the locality was, in the meanwhile, securely marked with buoys. Another cable having in the ensuing winter and spring been got in readiness, was this time without a single hitch or interruption laid along the bed of the Atlantic by the *Great Eastern*, which quitted her starting point off the coast of Ireland in Foilhommerum Bay on Friday, the 13th July, 1866, and reached her destination on the other side of the ocean on Friday, the 27th of July, there successfully landing the American end of the cable at Heart's Content in Newfoundland. Having accomplished this grand exploit, the *Great Eastern* almost immediately returned to her old fishing ground of thirteen months before in mid-ocean, and there with a hempen and iron rope six and a half inches in circumference, a line capable actually of bearing a strain of thirty tons in all, began, with gigantic grapnels, to feel anew along the bed of the Atlantic, at a depth of two and half miles, for the cable which had been so long before abandoned. On Friday, the 17th of August, 1866, its extremity was, moreover, absolutely dragged to the surface, and, there, though it was only for a few moments, actually seen! Not, in fact until the thirtieth time of dragging for it, was it in the end securely captured—the cable of 1865 being in its completed form at length safely landed in Heart's Content on Sunday, the 7th of September. Thanks to a combination of the Atlantic Morse alphabet, and of the mirror galvanometer, the intercommunication be-

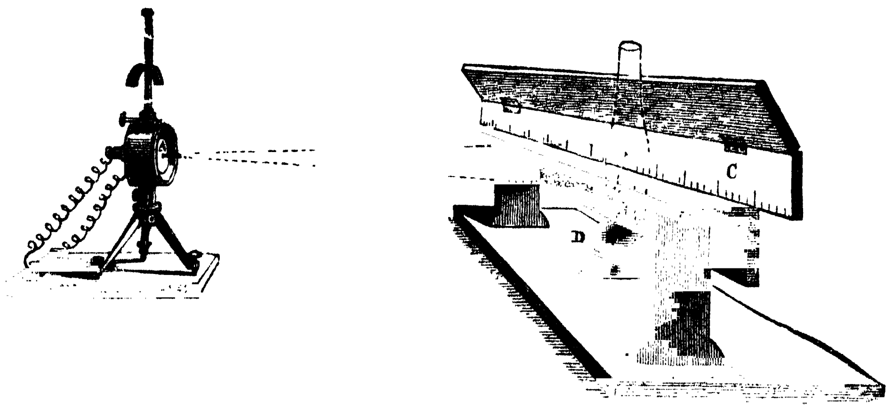

Fig. 38 —Mirror Galvanometer.

tween the Old World and the New, through the sub-oceanic cables of 1865 and 1866, has ever since been carried on with the utmost facility and velocity.

As for the Morse alphabet, it consists of nothing more than a variety of long and short strokes, which are capable of being glibly run off at the rate of a dozen words a minute. While, as for the magical mirror galvanometer, it is so exquisitely delicate in its structure that, including the tiny magnet cemented to its back, it weighs but little beyond a grain altogether, being no more than three-eighths of an inch in diameter, and the whole of it pendant from a single silk fibre! According to the light flashed from a reflected lamp through a lens by its vibrations, the signalling is read off by its recipient with wonderful ease and accuracy.

It will be understood at once in regard to the manipulation of the electric telegraph, that the current passing through the line has its cause in the transmitting station and its effect in the receiving station—the variations of the effect visible on the receiving instruments constituting in point of fact the signals. It is almost needless to add that the systems of signalling in actual use are numerous. Wheatstone and Cooke's needle system is of two kinds, either of which must be sufficiently familiar, to wit the double-needle instrument worked with a couple of line-wires and the single-needle instrument worked with no more than one wire. Their original patent for 1837 was one complicated with five wires and five needles, each needle having a right and left deflection from the perpendicular. That, however, was quickly superseded by the double wire two-needle telegraph, which was yet further simplified into the one wire single-needle instrument. Steinheil, however, it should be said at once, was the electrician who, as far back as in 1837, was the first to demonstrate that one wire was all-sufficient for the electro-magnetic telegraph, the line laid down by him to prove this being that of twelve miles intervening between Munich and Bogenhausen.

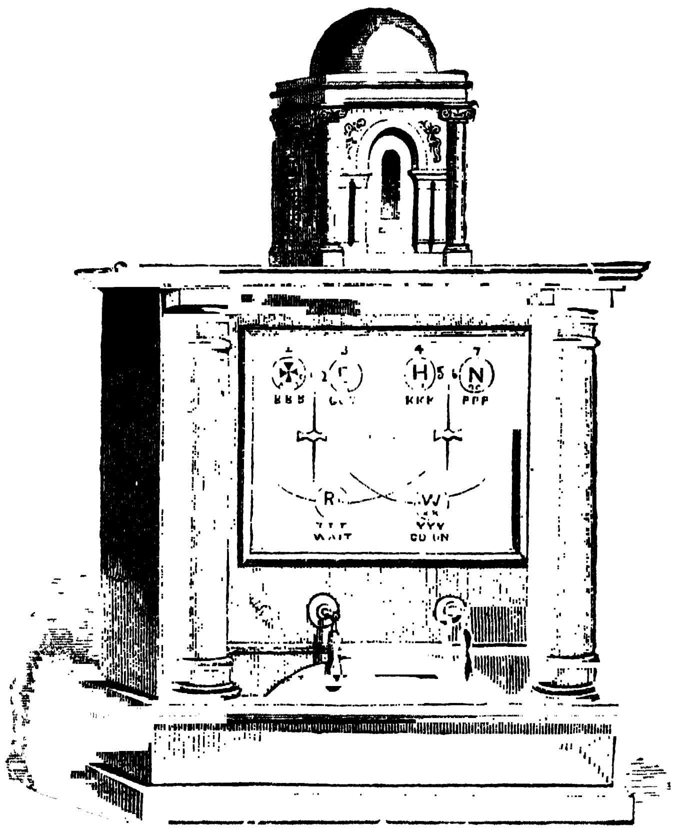

Fig. 39.—Cooke and Wheatstone's Double-Needle Telegraph.

His receiving instruments were of various kinds and of marvellous ingenuity. Contenting himself first of all with the clicking right and left movements of the needle, he next gave the telegraph more distinctly the power of speech, by causing it to ring a couple of bells, the recording clerk writing down the messages as they were spelt out to him solely through his sense of hearing. Steinheil's crowning achievement in the shape of a receiving and, it may even be added, a registering instrument, was through the employment of a couple of needles, one moved by the positive and the other by the negative current, each needle carrying a light tube of ink which, when deflected, marked a ribbon of paper that was drawn out by clockwork, and upon which ribbon the marks of the two needles were legible in a double row of dots. After this fashion it was that the electric telegraph came, for the first time, to jot down its own messages in enduring characters.

Another remarkable contrivance in the way of a rapidly worked single-needle telegraph, was patented in 1848, by the Rev. Henry Highton, M.A., and his brother Edward Highton, C.E.,—coupled with which was a three-screened letter-showing indicator, in the centre of a dial in the fixed screen of which a single letter at a time was revealed according to the fluctuations of three moveable screens at the back. Notwithstanding the indisputable beauty, simplicity and ingenuity of this invention, the triple-wire arrangement it involved presented a fatal bar to its general adoption. A couple of years previously the Rev. Henry Highton had patented in 1846, a yet more delicate indicator, also visible at the centre of a dial,—this being a tiny slip of gold leaf inside a glass tube, which morsel of gold leaf, forming part of the electric circuit of the line-wire, and having a permanent magnet in its near neighbourhood, moved to the right or the left accordingly as the current was positive or negative.

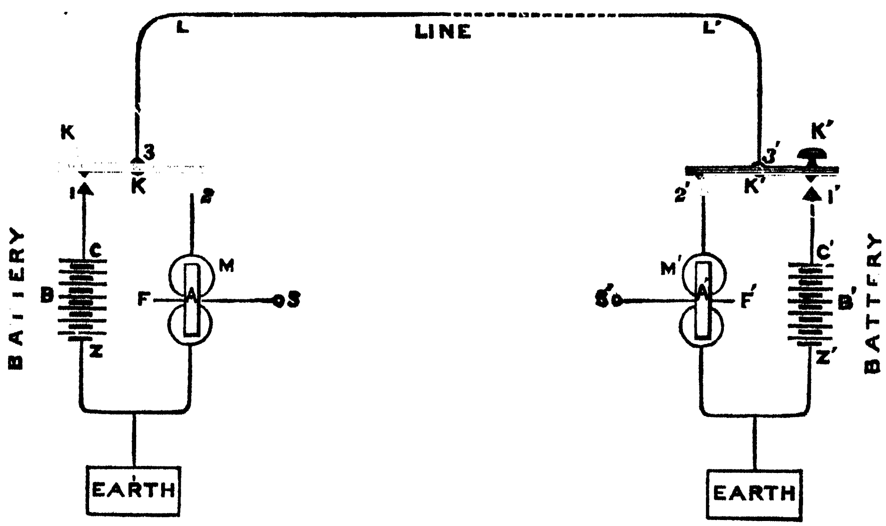

Fig 40.—Connection of Telegraphic Line with Morse Instruments.

Conspicuous among the evidences of Sir Charles Wheatstone's astonishing ingenuity as an electrician, were those afforded by his construction of his ink-marking automatic telegraph, whereby Steinheil's original scheme was in the end entirely superseded. Still more marvellous in its way, was his contrivance of an instrument for perforating paper, afterwards employed in an automatic sender as a means of supplementing Bain's original system for transmitting signals that were electro-chemically self-recorded. Bain's alphabet like Morse's was one of dots and dashes. It differed however in this from the American's system, that its signals were recorded by the current itself upon paper moistened with a solution of the yellow prussiate of potash slightly tinctured with nitric or sulphuric acid. Carried round by wheelwork on a circular brass tablet, the paper thus chemically prepared passed under the gentle and continuous pressure of an iron or copper pen-wire which, whenever the electric current flowed through it, uniting its dissolved metallic particles with the prussiate of potash, produced the well-known colour, prussian blue. The message thus permanently stained the revolving circular tablet (for which was afterwards substituted a long and gradually unwound ribbon of paper) with blue dots and dashes according to the intermittent thrills or throbbings through it of the electricity.

What was especially remarkable in this particular recording instrument, when employed in connection with the Atlantic cable, was the fact that the pen, never stirring but steadily bearing all the while on the paper ribbon, spoke visibly—according to the palpitations of the electric current momentarily stopped or set flowing 2,000 miles away,—in the alternating deep blue lines, and dots, and blank spaces which instantaneously started to view on the retreating surface! A supplementary contrivance of Bain's enabled the transmitting clerk, with the help merely of a long strip of paper in which lines and dots of varying size had been previously punctured, and which was then passed over a cylinder, to run off any lengthy document, such as a President's message, with the rapidity of one turning the handle of a barrel organ! By this means 500 letters were recorded in a single minute.

Whatever the electromotor employed—whether it be the galvanic battery, the volta-induction coil, or the magneto-induction instrument—about the simplest system of all is Morse's electro-magnetically self-recording telegraph. By it, Wheatstone's step-by-step system, formerly used for years together all over the European continent, has long ago been almost entirely superseded. Wheatstone's printing telegraph, however, more particularly supplemented as it was most effectively by House's American patent mechanism for carrying it into practical operation, for long held its own with the ablest contemporary contrivances of that character—such for example as even that extraordinary product of electro-magnetic mechanics, Hughes's bell-ringing, needle-clicking, ribbon-running, type-printing telegraph, the watching of the working of which is like the visible realization any day of the wildest dreams of mediæval necromancy.

Two other marvellous additions to the Electric Telegraph—each of them but very recently perfected—ought here, however, to be particularized as threatening to supersede both those last-mentioned. One is an ingenious piece of mechanism contrived by Moore and Wright for wiring messages in Roman type—not like those of House and Hughes on an endless tape or ribbon, but—in printed columns, line under line, and page after page, such as are set up by an ordinary type-writing machine. This, it will be recognized at once, marks a distinctly new epoch in the history of electro-mechanical telegraphy, for the record thus produced by the receiving apparatus of the electric telegraph, admits of being bound up afterwards, book-fashion like the leaves of any other volume.

This contrivance of Moore and Wright's, which is worked by a single wire, contains within it two clock-work trains—one turning the type-wheel, and the other feeding the paper upwards at the close of each line, and then returning the type-wheel, from right to left, to the beginning of the next line. The releasing of the clock-work, which alternately feeds the paper upwards and returns the type-wheel to its first position, is effected by the action of an auxiliary magnet, to the armature of which two releasing fingers are attached, which fingers act upon a pin fastened to a pinion at the last position in the train. Immediately on the magnet being sufficiently charged to attract its armature, the fingers are moved into the proper position, the paper not being fed upwards until the current ceases,—the armature, thereupon, being withdrawn by means of a spring. As for the feeding of the type-wheel laterally, that is effected by the agency of two racks—one stationary, one moveable. What immensely enhances the value of Moore and Wright's machines is the fact that any number of them can be set in movement from one operating centre at the sending end of the electric telegraph.

Another and all but magical addition to the Electric Telegraph more recently perfected by Professor Elisha Gray, of Illinois, actually accomplishes the astounding feat of transmitting a message to any distance through the telegraphic wire in the sender's own handwriting! Hence it is aptly called by its inventor the Telautograph. The device consists of two current interrupters at the writing end of the electric wire actuating two electro-magnets at the receiving end. Suppose that a message has to be telegraphed from London to Liverpool, the sender writes it (on the endless tape, automatically fed out of the electro-telegraphic machine), with a pencil to which two threads are attached at right angles, kept at an even tension and connected with the interrupters—these threads not interfering in the least with the free movements of the pencil, every one of which all the while interrupts the electric current. Meantime, 200 miles away at Liverpool, a stylographic pen, fitted with two electro-magnets, is so fixed on a pivot at the receiving end of the wire immediately above the endless tape there streaming out of the telegraph machine, that every interruption of the current moves the pen exactly as the sender's pencil is moving at the same instant in London. In this way is reproduced a literal *facsimile* of the sender's own handwriting, the latter being able to file his original copy for after reference. What completes the marvel of this contrivance is the fact that, while no variation occurs in the electric current, no special machinery of any kind is required for the manipulation of the Telautograph.

If, as is unquestionably the case, the electro-magnetic telegraph may be said quite truly to have sprung into existence originally here in England, it must with equal truth be added that it reached its actual state of perfection in America. And as if to emphasise in the tersest manner the fact that it has done so, I would here in conclusion remind my reader that, not from the United Kingdom but from the United States, has come that compactest telegraphic signal of all, familiar now in both hemispheres, "O. K.," which whimsical little scrap of Yankee humour on being interpreted is found to signify All Correct!

III.—THE PHOTOGRAPH.

"To hold as 'twere the mirror up to nature."—SHAKSPEARE.

A CAMERA OBSCURA is, surely, about as exquisitely beautiful a contrivance as the ingenuity of man ever hit upon. Its inventor, according to the popular notion, was Giambattista della Porta, who flourished towards the close of the sixteenth century. As a matter of fact, however, three hundred years before then, Roger Bacon, the famous Franciscan monk, had accurately described the manner of its construction. Compared in 1500 by Leonardo da Vinci to the structure of the eye, it was, exactly two centuries later, that is in 1700, remodelled and in some sort perfected by Sir Isaac Newton.

As its very title indicates, it is to all appearance nothing more than a darkened chamber. Enter a Camera Obscura, however, for the first time in your life, and no sooner has the door, by which you have just gained admission to the little circular edifice, swung to upon your heels, than it will almost seem as though you were gazing down, there, into the Magic Mirror of a necromancer. For, immediately in front of you, to your amazement, you will perceive—upon the luminous disc of a small round table rooted in the centre of the otherwise perfectly dark apartment—a living and moving picture such as nothing less, you would say, than the wand of a magician could by any possibility have conjured into existence. Whence the mysterious light can have come, by the aid of which each minutest particular is revealed in the animated panorama there unfolded to your view, will appear utterly incomprehensible. For, so far as is apparent, every ray of the outer daylight has been most carefully excluded.

Nevertheless, accordingly as the Camera you have entered has been planted, let us suppose, upon a cliff by the seashore, or upon an eminence in the midst of woodland scenery, or upon an elevation overlooking the thickly-peopled public square of a great city, or the esplanade of a fashionable watering-place—there, before you, in the magical picture revealed in miniature upon the disc of that wonderful table, the waves visibly roll and seethe along the shore; the leaves flutter and twinkle in myriads upon the branches; the motley concourse jostles in the crowded thoroughfare; the idle saunterers lounge at their leisure: every lightest gleam and movement and flicker in the scene disclosed being from one moment to another microscopically distinguishable. Whatever the comparatively distant view out of doors may be, there,—upon the white disc of the Camera,—in every atom of it, in light and shade, form and colouring, it is most faithfully reflected.

Now, supposing that Roger Bacon when, more than six hundred years ago, he drew up, at the request of

Fig. 41. - Roger Bacon.

Pope Clement IV., the record of his scientific achievements in his "Opus Majus," a copy of which is still preserved among the Cottonian manuscripts,—supposing, I say, that he had followed up the description he there gives of the marvels of the Camera with the assertion that the fleeting pictures it reveals were capable of being caught and fixed and perpetuated and multiplied to any extent, the most sagacious of his contemporaries, to put it mildly, would have regarded him as expressing his thoughts for once in words of the wildest extravagance, while upon the other hand the ignorant rabble of his time would have been more than ever persuaded that he was in truth no better than a wizard. And yet, after all, this is precisely what has been actually accomplished in our own day by the marvellous art of photography! Through its agency, by means of a subtle blending of optics and chemistry, the picture thrown by the lens of the camera upon a plate of glass is in very deed caught and fixed and perpetuated and indefinitely multiplied. Every delicate gradation of light and shade is there scrupulously preserved. Nothing, in fact, but colour is wanting to complete the illusion. And so astounding has been the development of this exquisite art, since its first announcement just fifty years ago (in 1839), that it is impossible not to look forward hopefully to the time when, by some as yet unconjectured perfecting process, the natural colour of every object reflected upon the sensitised plate of the camera may be revealed no less accurately than the most evanescent lights and shades of the completed photograph.

As a miniature camera is the first essential among the apparatus of the photographer, it will be obviously advisable to explain at once in a few words the principle upon which it is constructed. A portable box—which, for the mere purposes of adjustment, the operator can peep into from the rear as into a puppet-show—takes the place in this instance of the more substantial structure which the spectator was obliged to enter bodily before he could see anything at all of the wonders of the Camera Obscura. Oblong in form, this compact mahogany shell, so to speak, of the photographic camera, is in two compartments, one sliding within the other,

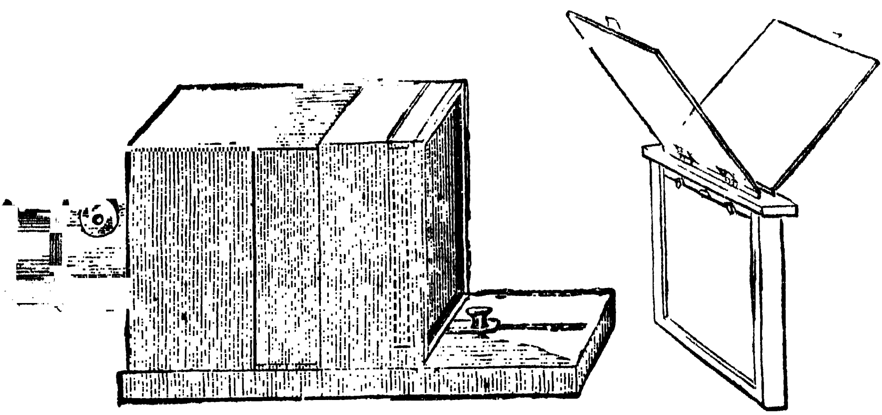

Fig. 42.—The Camera and Plate-holder.

so that by means of a screw—just as an opera-glass can be wound or unwound to the proper focus—the box as a whole can be lengthened or shortened at pleasure. At the front of the camera, that is in the centre of the smaller of its two divisions, is a circular orifice—occupied permanently by the lens and the lens-holder. At the back or butt-end of the broader division is the square, grooved framework of what is known as the plate-holder—occupied, this latter, alternately (accordingly as the apparatus is at rest or in action) by a plate of ground glass, or by a plate of transparent glass which last is filmed over, on the side towards the lens, with a translucent veil or membrane of wonderful sensitiveness. It is by the mysterious action of light upon this most delicate film that the picture thrown upon it by the lens, from whatever scene or object confronts the opposite extremity of the camera, is all but

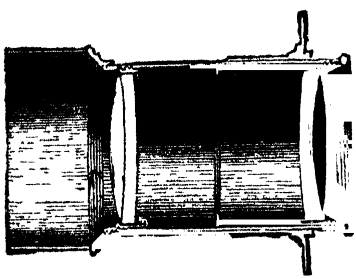

Fig. 43.—Section of Lens-holder.

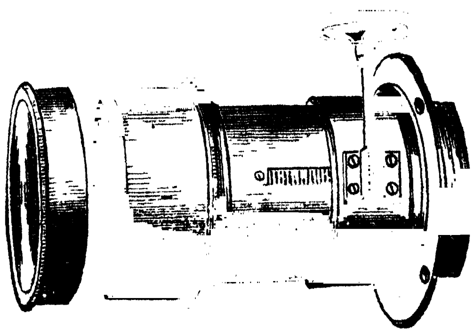

Fig. 44.—Cap and Lens-holder.

miraculously fixed and perpetuated! How possibly to catch the fugitive image shadowed forth by the lens upon the screen of the Camera Obscura had long been among the cherished day-dreams of more than one great natural philosopher. And how it was that, little by little, this seemingly fantastic day-dream came at length to be actually realized, it will be my agreeable office here step by step to relate.

Probably the first glint anywhere discernible of the dawn of photography as a science—photography as an art not being dreamt of until long afterwards—was that afforded in 1566 by Fabricius, when he directed attention to the surprising fact that under the influence of light, salts of silver invariably change colour. His observation as to the power thus exercised by the sunbeam upon certain substances was more than confirmed in 1722 at Paris, by Jean Petit's discovery that solutions of nitrate of potash and muriate of ammonia crystallise much more readily in light than in darkness.

But little more than half a century after the latter fact became known, the Pomeranian philosopher, Carl Scheele, of Stralsund, first drew attention in 1777 to the curious circumstance that upon his pouring chloride of silver over a lump of chalk, and upon his exposing the latter when thus saturated in a glare of sunshine, it very soon became blackened. Further than this, Scheele made clear by his experiments the still more remarkable fact that chloride of silver underwent this discoloration much more rapidly in the blue and violet than in any other rays of the solar spectrum. His declarations to this effect were shortly afterwards fully confirmed by the researches of Senebier, who demonstrated at the close of a long and exhaustive enquiry that whereas no less than twenty minutes were consumed before the red ray accomplished the blackening of the chloride of silver—twelve minutes exposure in the orange ray were required to produce the same result, five minutes and thirty seconds in the yellow, and thirty-

Fig. 45.—Sir Isaac Newton

seven seconds in the green! Beyond which it needed no more than twenty-nine seconds in the blue, and as brief an interval as fifteen seconds in the violet to cause precisely the same amount of discoloration. At the date of Senebier's ingenious calculation, but little more than a century had elapsed since Newton in 1666, armed merely with a small triangular bar or rod of glass, had succeeded in establishing at last the true theory of colours.

Admitting a sunbeam through a minute orifice into a dark room, he there made visible the fact that upon shooting the arrow-like pencil of white light through a speckless prism, it was not only bent or refracted from the perfectly straight course it had previously held in its descent earthwards, but that in its divergence it spread out fan-wise, through and beyond the prism, into seven distinct colours of surpassing splendour—Red, Orange, Yellow, Green, Blue, Indigo, Violet—each overlapping its immediate neighbour, and thus becoming shaded off the one into the other in imperceptible gradations. A hundred years having run out from the time of that magnificent revelation, Scheele, during the later half of the eighteenth century, was the first, as has been shown, to direct attention to the exceptional influence exercised by light, and especially by the blue and violet rays of the spectrum, upon certain compounds of silver.

Another chemical enquirer, going further than this a score of years afterwards—Jeremiah Ritter of Silesia, by name,—demonstrated in 1801 the existence beyond the violet end of the spectrum, of black or invisible rays, the reality of which was made plain by the power they evidenced of rapidly darkening chloride of silver. His startling conclusions were fully borne out, here, in England, by the nearly simultaneous experiments of Dr. William Wollaston. Meanwhile other philosophic

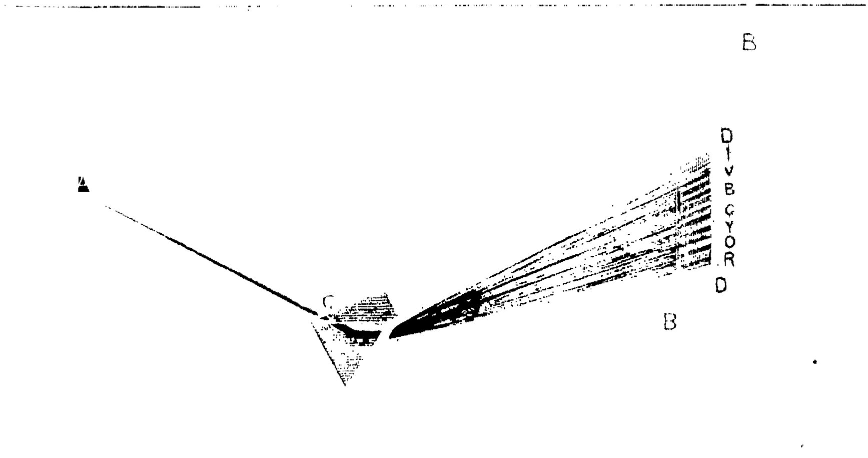

Fig. 46.—Newton's revelation of the Solar Spectrum.

investigators were diligently putting to the test the ideas which occurred to them during their examination of these surprising phenomena, notable among them being Sir William Herschell and Sir Henry Englefield.

At length, however, in the June of 1802, there appeared in the *Journal of the Royal Institution* a brief but remarkable paper, announcing the first successful attempt to produce pictures by the aid of sunshine. Its writer, afterwards famous as Sir Humphry Davy, had only a few months before this, in the twenty-third year of his age, become assistant lecturer at that establishment. His account of the newly-discovered "Method of copying paintings upon glass and of making profiles by the agency of light upon nitrate of silver," is included among his collected Works (vol. ii. p. 240) as the twenty-second of his early miscellaneous papers. Slight and sketchy though it is, it contains within it, nevertheless, the complete germ of the art of photography. As its very title intimated, the merit of the invention belonged exclusively to Thomas Wedgwood, the brother of Josiah Wedgwood of Etruria, the great potter and porcelain manufacturer.

All that Davy had to do with the matter was to explain the nature of the discovery by a few observations. In these, attention was for the first time directed to the fact that whereas white paper or white leather when moistened with a solution of nitrate of silver undergoes no alteration whatever in darkness, it becomes successively grey, brown, and eventually black, on exposure to the daylight. Aware of this and aware at the same time of the different rate at which the rays of the spectrum (as shown by Senebier) exercised their darkening influence upon the nitrate of silver, Wedgwood conceived the notion of interposing a painting on glass between the daylight and such prepared paper or leather.

Fig. 47.—Dr. William Wollaston.

When put to the test, his idea fully answered his expectations. There, very clearly defined upon the white paper or the white leather, was a shadowy presentment of the glass painting! Similarly, if any object, such as a fern leaf or a fragment of lace or the wing of a butterfly, were placed upon the white paper or the white leather, before its exposure to the daylight, a faithful effigy of whatever had thus protected either material from the darkening influence of the sun, was formed in spectral white underneath. In making these experiments the instruments employed were, first of all, ineffectually, the Camera Obscura, and afterwards very effectively, the Solar Microscope.

Pictures, profiles, and the outlines of all kinds of natural objects were thus readily obtained—the one only drawback in regard to the invention being this, that the representations thus secured could only be examined furtively in a dark room, they being in themselves of the most evanescent character. Wedgwood in fact, even with the assistance of Davy, failed altogether in his endeavour to fix those first photographs, and thus to render permanent the earliest sun-pictures ever produced. Unless they were carefully kept in a dark place, their whole surface became rapidly blackened.

Sir Humphry Davy's concluding remark when making the announcement of Wedgwood's discovery is especially worthy of note.—"Nothing," he wrote, "but a method of preventing the unshaded parts of the delineation from being coloured by exposure to the day, is wanting to render this process as useful as it is elegant." During the following year (1803), it is true that Sir David Brewster called attention to what had thus surprisingly, though only fugitively, been accomplished. But, apart from that, fully ten years had

Fig. 48 —Sir Humphry Davy.

elapsed before any further attempt was made to hold up Wedgwood's achievement in any way as an incentive to other optical or chemical experimentalists.

At Châlon-sur-Saône, however, in 1813, a new investigator of these subtle departments of natural philosophy appeared in the person of Nicéphore Nièpce, whose ambition from that time forward until his premature death in 1833, was to effect the production of permanent pictures by the agency of sunlight. In the carrying out of this ambition, it is only justice to his memory to say at once that, upon the whole, to a very considerable extent, his efforts were successful. By the year 1822 he had contrived a process by means of which he obtained copies of engravings upon plates of polished pewter, or upon silvered copper tablets, or upon glass, each of which had been previously coated over with a sensitive bituminous varnish of his own composition. It is now known that the substance employed by him in this manner was asphaltum or bitumen of Judæa. Having first covered a plate, of either glass or metal, with a solution of the mineral pitch, previously dissolved by him in essential oil of lavender, he, so soon as the varnish thus filmed over it had become sufficiently dry for use, exposed his sensitised plate under an engraving in the Camera, where it had to be subjected to the influence of the sunbeams for about five hours before the latent image was in a fit state to be developed. For the purpose of bringing about this development, the solvent employed by him to act upon the consumed portions of the varnish was composed of certain adroitly mingled quantities of naphtha or white petroleum and oil of lavender. Under the operation of this potent menstruum, the hidden picture upon the plate in due course made its appearance; when immediately upon its starting to view, it was seen that the lights in the design were the insoluble portion of the tenacious bitumen, while the shadows were no other than the surface of the plate itself. Finally, as the perfecting stage of the process, the plate was carefully swilled over with water, so that the last particles of the solvent which had been used should be effectually cleared away. Such was the beautiful process contrived by Nièpce for the production of sun-pictures, a process which was accurately and elegantly designated by him Heliography.

Coming over to England in the autumn of 1827 on a visit to his elder brother at Kew, Nicéphore Nièpce on the 8th of December transmitted thence to the Royal Society in London a paper having reference to his invention, which he accompanied with several specimens of the heliographic art it announced. Seeing, however, that throughout this paper the writer kept his method a profound secret from the learned body he was addressing, the Royal Society was precluded by one of its initial rules from taking any notice whatever of his communication. Having it, in consequence, returned upon his hands without any acknowledgment, together with the specimens by which it had been accompanied, the discoverer of heliography went back to France soon afterwards with a rather poignant sense upon him of chagrin and discouragement. Meanwhile another remarkable French experimentalist, unknown to Nièpce, had been for upwards of three years, counting from the early part of 1824, applying all his energies to the endeavour to find out some means of fixing the pictures in the camera. This was no other than Louis Daguerre, already known even then to the public at large in Paris both as a painter and as a physicist, he having indeed by that time acquired a certain amount of celebrity by right of his ingenious contrivance of the Diorama.

For nearly seventeen years together—from the 11th July, 1822, when his Diorama was opened, to the 3rd March, 1839, when it was destroyed by the act of an incendiary—fortune as well as fame poured in abundantly upon Daguerre, whose then apparently complete ruin by that overwhelming disaster, proved to be only the immediate prelude, as the result showed, to his acquiring, in a very different way indeed, a far wider and more enduring reputation. His researches in regard to the action of the light upon certain silvery solutions had been continued for some time, unknown to anyone outside his own *atelier* and laboratory, when information reached him of the kindred enquiries which had been so long prosecuted by Nièpce at Châlon-sur-Saône. Daguerre at once put himself into communication with the latter, the correspondence of the two ending at last in their meeting one another in Paris, and, on the 14th December, 1829, entering into formal partnership. That partnership in fact was only closed by the regretted death of Nicéphore Nièpce on the 5th July, 1833, just six years prior to the fruition of all their hopes in Daguerre's great discovery. With the survivor's name the glory of that discovery has been almost exclusively associated. But there can be little doubt that a large share of the credit of it is due by right to the earlier of these two enquirers. Nièpce it was, indisputably, who, with a view to produce a better effect in the metal tablet they had to manipulate, suggested the darkening of the silvered surface of the copper plate with a film of iodine—to which proposal Daguerre was indubitably indebted for the notion of employing that material.

It was in the January of 1839 that the magical process now known all over the world as the Daguerreotype was, to the delight and astonishment of the civilised nations of the earth, publicly announced. What had so long been the day-dream of so many philosophical enquirers was at length actually accomplished—the reflection of natural objects, the shadowy pictures of the Camera Obscura, were actually caught, there, upon metal tablets, and so securely fixed that they might be preserved thenceforth in perpetuity!

Although the fact of this wonderful discovery was made known, as has been said, with the very dawn of 1839, half a year was allowed to elapse before any detailed description of the process came before the world; arrangements having in the meantime been made by the French government for the securing of the interests of the in-

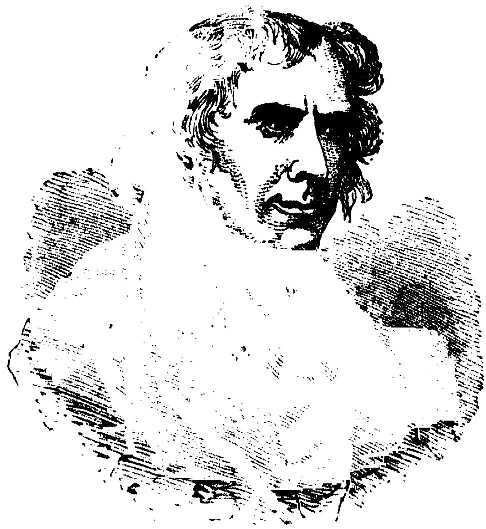

Fig. 49.—François Arago.

ventor and his immediate colleague, Isidore Nièpce, the son of Nicéphore, with whom, shortly after the latter's death, Louis Daguerre had entered into partnership. To this end, at the instance of Arago, to whom the secret of the invention had been originally confided, a bill was passed through the French legislature bestowing a pension of six thousand francs a year upon Louis Daguerre and another of four thousand a year upon Isidore Nièpce; a bill which after having received the approval of both chambers, was signed on the 15th June, 1839, by king Louis Philippe.

François Arago, when first introducing the measure to the consideration of the chamber of deputies, intimated in the name of the crown and of the executive that France had formally adopted the discovery, and that from the first moment of its coming to her knowledge she had cherished a pride in the thought of liberally bestowing it, as she then did, as a free gift to the whole world. So far as England was concerned, Daguerre, through some unlucky misapprehension on his part as to this same free-gift of his invention to the world at large by the French government, had, before it was too late, sold a monopoly of his process within the United Kingdom to Mr. Miles Berry; to whom, in consequence, the officers of the crown, thereupon, granted a patent forthwith. Hence, for eight years together, with no little consequent discredit to the inventor, the photographers in this country were debarred from freely availing themselves of the privilege enjoyed elsewhere of practising the new art without let or hindrance, in which case they might at once have produced for their own advantage any number of daguerreotypes.

Briefly expressed, the production of a daguerreotype involves, first, the spreading of a film of iodide of silver over a plated copper tablet; secondly, the exposing of that film for a comparatively short interval to the image of the camera; and thirdly the subjecting of it in a darkened room to a vapour bath of heated quicksilver. During the last-mentioned of these three subtle processes, the steam of the mercury is, in some inexplicable manner, deposited by condensation upon those parts alone of the sensitised plate which had been more or less illuminated in the camera, the latent image, until then invisible, starting to view with marvellous distinctness under the influence of this

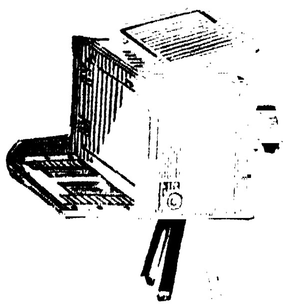

Fig. 50.—Tourist's Camera, ready for use.

magical medium for its development. Although the daguerreotype has for a good many years now been superseded so entirely that it is but little more than historically noteworthy, it is so eminently beautiful in itself, and is so memorable besides, as having been the first finished specimen of the caught image of the camera, that the manner in which it was produced by the manipulator cannot but still be matter of the profoundest interest to every intelligent inquirer into the mysteries of the rise and progress of the photographic art.

A silver plate was first employed by Daguerre as the tablet on which the reflection of any object in the camera was fixed indelibly. Later on, he found that just as perfect effects were produced upon a more economical tablet of sheet-copper plated over with silver. Having selected his silver-plated copper tablet, he then cleansed and polished its surface with the greatest care. So soon as he had got it thus into the glossiest condition, he subjected it to the fumes of dry iodine until it had become so completely and visibly covered all over with a delicate film of iodide of silver as to present to view an extraordinary variety of colours. Those opaline hues as a matter of fact were consequent as he knew upon the amount of iodine which had been absorbed.

Immediately the plate had become thus sufficiently iodised, the right moment for this being indicated by the richness of its tinting—when the rosy dyes were deepening, that is, to a ripe orange-yellow bordering upon red—he then, but not until then, placed it, in its highly sensitised condition, in the dark slide of the Camera Obscura, where for a given time it was exposed to the light passing through the convex lens, at the precise focus of the instrument. Whenever a sufficient interval had elapsed to make him feel confident that a crisply defined picture had been obtained of whatever strongly illuminated object happened at the moment to confront the lens of the camera, the plate, carefully concealed by him in its shuttered holder, was conveyed back to the darkened room in which it had previously been sensitised. There it was, in a box ingeniously constructed for the purpose, exposed to the fumes of mercury heated sufficiently to evaporate at a rather moderate temperature: the cloudy mist of quicksilver having the wonderful property, as has been intimated, of attaching itself merely to such parts of the iodised plate as had received the light upon it with greater or less intensity.

Exactly in proportion to the actinic action of the light upon the iodised silver, the mercurial vapour is deposited ; the latent picture in the film—as those fumes become attached—rising to view by a marvellous process of development. Thereupon the picture originally thrown by the lens of the camera on the metallic plate, having in this mysterious way been rendered visible upon it after it had left the camera was by another and an equally simple process fixed there permanently. It was so fixed by the immersion of the plate in a solution of hyposulphite of soda. By dipping it freely in fact into a bath of that character whatever iodide of silver yet veiled the shadows of the picture was thoroughly dissolved and swept away, so that the surface of the plated copper was no longer anywhere susceptible to the darkening influence of the sun-light.

At this stage of the process the daguerreotype, having ceased to be in any way sensitive, was plentifully washed over with clean water, and when dried could be looked upon as finished. As a safeguard against the chances of dust and friction, it was then by a reasonable precaution placed under a sheet of glass and securely framed, or put into a case for preservation.

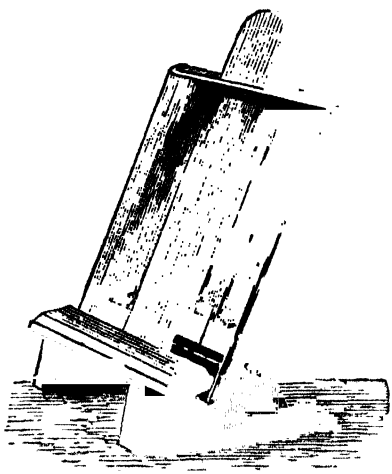

Fig. 51.—Dipper in Bath.

Microscopically exact though all the details of a daguerreotype are, and luminously beautiful though its general effect is, it is little less than marvellous to find upon looking into it very carefully, that the lights of the picture are merely the deposit of a mercurial vapour, and that its shadows are no more than glimpses, in between, of the highly polished surface of the silvered copper-plate. Wherever the suspicion of a stain may appear to threaten one of these miracles of art with extinction, that stain may generally speaking be completely removed by flooding the plate for a few seconds with a solution of cyanide of potassium. In obedience to a suggestion from M. Fizeau, the daguerreotype was not only greatly improved in appearance, but rendered besides that far more durable by having the image upon it filmed over with gold by a spontaneous electro-chemical action. The rapid production of it, moreover, was greatly facilitated, thanks to Mr. Goddard's simple device of combining bromine with iodine, thereby enabling the picture to be taken not in a few minutes, which to a nervous sitter appeared ages, but in that little more than mere twinkling of an eye—a few seconds! At a later date Claudet suggested the combination of chlorine with iodine, but as a rule the blending of bromine with the latter proved to be so far more effective, that, to this day, wherever the art survives, that solution is still employed by preference.

Fully half a year before Louis Daguerre's wonderful process was given to the world by the French government, Henry Fox Talbot, on the 30th of January, 1839, announced to the Royal Society his own no less marvellous discovery. This, dubbed by himself the Calotype process, was more generally known among the public at large as the Talbotype.

To explain in a few words the system adopted by its inventor, it will be sufficient to remark that he began by washing over one side of a sheet of good letter paper with a solution of iodide of potassium. Immediately it was dry he washed it over anew, this time, however, with a solution of nitrate of silver with which a very small quantity of acetic acid had been combined. Directly this also was sufficiently dried, the paper was washed over for the third time but in that instance with perfectly clear water. Prepared in this way it might be kept for some considerable time in readiness for use without much risk of the delay proving detrimental. Whenever the moment came when this paper had to be employed, another solution for it was made consisting of a few drops of diluted nitrate of silver mixed with about an equal quantity of saturated solution of gallic acid. So soon as these were thoroughly intermingled they were spread delicately with a glass rod over the prepared side of the paper, which was thereupon placed at a proper focus in the camera to receive whatever image was thrown upon it by the lens. A brief interval having elapsed a picture, as yet quite invisible, was imparted to the sensitised paper, which was forthwith, in a shrouded condition, conveyed from the instrument into a dark room or closet where it was once more washed over with the mixture last mentioned, popularly known as gallo-nitrate of silver. During its ablution, thus, the latent picture slowly becomes apparent. And immediately it has started crisply to view, the action of the gallo-nitrate of silver upon it is abruptly arrested by plunging the paper into water. It is after this that the picture is fixed, and the tawny colour of the iodide of silver at the same time effectually removed by the application to it of heated hyposulphite of soda. A picture thus obtained is nothing more, it is true, than what is termed a Negative—that is, one in which the lights and shades of it are completely reversed. But from that Negative any number of Positive pictures may be readily obtained by the simple plan of laying it just as it is upon fresh sheets of sensitised paper in due succession, and allowing the light to pass to each through the interstices of the shadows of the negative. Obviously, indeed, the negative is not in itself strictly speaking a picture at all, but merely the medium from which may be obtained the positive picture, which is the one ulterior object of the photographer.

What constitutes the chief glory of Fox Talbot as a photographic originator is this, that, besides having been the one to suggest the marvellous process of developing the latent image with the agency of gallic acid, he was unquestionably the one who first discovered the means of suddenly arresting the actinic action of the daylight, and of fixing indelibly upon the sensitised paper the image which had been mystically traced there in the camera by the sunbeam. Immediately the picture had been sufficiently developed by the gallo-nitrate of silver, he checked all risk of the light acting any further upon it by washing it over with a solution of bromide of potassium.

Fox Talbot it was, besides, who by hitting upon the simple arrangement of first of all producing a negative and then from that negative printing off any number of positive impressions, gave the art of photography its immense commercial value and importance. As far back as in the spring of 1834, when, as it happened, he was entirely ignorant of what Wedgwood had so long before accomplished in the same way he had succeeded in taking pictures with the camera by the action of light upon paper rendered sensitive to its influence by having been previously washed over in the manner described with a solution of nitrate of silver. Beyond this, he had, even thus early, obtained some glimmering of a notion that he might find it possible to fix the image, as he actually did in the end, indelibly. His first method of accomplishing this all-important object was by immersing the calotype in a strong solution of common salt and water, in which briny bath all the unaltered parts of the chloride or silver were effectually dissolved.

Although Daguerre and Fox Talbot came to the front almost simultaneously in the January of 1839 with their respective processes, those two processes, as will have been remarked, were essentially different. Among the means employed to the same end by the inventors of the Daguerrotype and of the Talbotype, none could be said to have been in common between them beyond the daylight, the lens, and the Camera Obscura. Fox Talbot's first paper, the one read by him before the Royal Society in January, 1839, described what he called the art of Photogenic Drawing, or the process by which natural objects might be made to delineate themselves without the aid of the artist's pencil. His second paper, the one read by him on the 21st February, entered more into details in regard to his discovery, relating rather minutely, among other things, the method employed by him in preparing the sensitive paper, and that devised by him for fixing the images obtained in the camera.

A couple of months after this, in the April of 1839, the Rev. J. B. Reade was enabled, in consequence of these papers of Fox Talbot, to produce life-like representations of various objects of natural history by the agency of light directed through the solar microscope. Having washed over a sheet of writing paper with a powerful solution of nitrate of silver and having immediately before using it, yet further washed it over with an infusion of nutgalls, he then so placed it that, while it was yet moist, it had the microscopic image directed full upon it. Pictures thus obtained were fixed by him with hyposulphite of soda. Another ingenious device, obviously in like manner the outcome of Fox Talbot's photogenic revelation, was hit upon in the following month when, on the 29th May, 1839, Mr. Mungo Ponton, in an address to the Royal Scottish Society of Arts, brought to light the fact that paper when soaked in a saturated solution of bichromate of potash assumes a deep orange tint upon exposure in the sunshine. Having realized this fact, upon his placing dried plants from a *hortus siccus,* or an engraving from a portfolio, upon paper thus prepared, he found that the negative pictures of either thereby produced, were defined in dark orange upon a yellowish ground. To fix the image thus obtained nothing more was required than the immersion of the paper in water, by which means those portions of the salt not already acted upon by the sunlight were effectively dissolved.

Consequent upon this curious and invaluable discovery, a number of other enquirers in various parts of Europe were led soon afterwards to no less important results. Several entirely new processes in fact thus suggested themselves in rapid sequence. Notably among these were some contrived by Signor Sella in Piedmont and by Mr. Shaw at Edinburgh. In this way also the notion of preparing photographic paper with iodide of starch arose in the mind of M. Edmund Becquerel, while Mr. Robert Hunt, under the same direct incentive, was inspired to set forth his admirable process for the production of the Chromatype.

Metal plates, besides, were by various means from that time forward sufficiently engraved by the united action of light and chemical force to admit of their being printed from! Among other arrangements to this end, was the following:—A steel plate had poured upon it a warm solution of bichromate of potash and gelatine, which was allowed to dry in darkness. Having been dried in this way, a negative was placed upon it, and when thus partially veiled, it was exposed to the light. Thereupon, whatever chromic acid in the dried solution came to view, was reduced by the simple action of light to sesquioxide of chromium; the oxygen at the same time passing into the gelatine, which was thereby transformed into an insoluble substance. Upon the surface of the varnished plate being then moistened, those portions of the film which had not actually fallen under the actinic influence of the light swelled up, while the remaining parts continued at their original level. This being so, a mould was taken of the picture thus produced in relief, and from that mould a copper-plate was electrotyped, from which impressions were readily taken on an ordinary printing-press. Such in point of fact was the principle of the process which eventually came to be known far and wide as that of Photo-Galvanography. According to another and totally different arrangement, if, in lieu of allowing the gelatine not yet acted upon by the light to swell up, it were entirely dissolved and washed away with water, those portions of the steel plate which the light had not influenced being thus laid bare, could be readily bitten in with nitric acid; from the action of which acid the portions covered with insoluble gelatine would be effectually protected. And from this, in any ordinary copperplate press, impressions could be easily worked off in rapid succession. Supposing on the other hand that, instead of a metal plate a lithographic stone were thus prepared and brought under the action of light, immediately upon its being moistened its surface accordingly as it had been veiled or revealed by the super-imposed negative was enabled relatively to attract or repel grease and water—the result of that attraction or repulsion being Photo-Lithography.

Long before any of these processes had been dreamt of, however, long before Daguerre's beautiful discovery had become known to any one outside his laboratory, Fox Talbot had entered quite independently upon the researches already described. These led him in the end to the admirable photographic system of manipulation which was patented by him on the 8th February, 1841, supplemented by improvements of more or less value suggested among other experimentalists by Herschel, Bingham, Cundell, Müller, Channing, Le Gray, Stewart, Furlong, Everard, Sagnez, Collen, and Flacheron. Prior to all these, however, Mungo Ponton, at as early a date as in the April of 1839, had—by his remarkable discovery that paper could be rendered sensitive to the action of light by the simple process of suffusing it with a solution of bichromate of potash—been really the one to lay the foundation of very many of the photographic systems which have just been enumerated.

A revolution of the completest kind, however, was made in the whole process of photography, first in 1848 by M. Nièpce de St. Victor of Paris, and afterwards in 1850 by Mr. Scott Archer of London. To the former, the world is indebted for what is known as the Albumen Process, while to the latter a yet larger debt of gratitude is due for his suggestion of the use of Collodion. A plate of glass was in each instance sensitised by having a delicate film imparted to it before its having thrown upon it by the lens the image of the camera. Albumen, otherwise the white of egg, according to Nèipce de St. Victor's process, was suffused over glass in combination with bromide and iodide of potassium, with which a drop of caustic potash had been intermingled. Coagulated upon the surface, it was then exposed to the fumes of iodine, and after being silvered over in a bath of nitro-acetate of silver, was again passed over the fumes of iodine. Thus prepared, it was introduced into the camera, the image reflected upon it there being afterwards developed by a solution of gallic acid, and fixed securely by a solution of hyposulphite of soda. Drying finally as it does to an exceedingly tough and transparent film, it furnishes a Negative, from which there can be rapidly printed off under the actinic action of light any number of Positive Photographs.

Wonderfully ingenious and serviceable, as the Albumen Process undoubtedly is, however, it has long since been almost entirely superseded by Scott Archer's yet more marvellous process of taking photographic negatives with the aid of Collodion. This it is which, in the art industry of the world, has given to the photograph its unapproachable pre-eminence. Collodion, which is nothing else in fact than a slimy solution of gun-cotton dissolved in ether and alcohol, was first spoken of by M. le Gray as a material which might one of these days be turned to serviceable account in the development of the art of photography. Although Scott Archer had seen his way to the best method of acting upon this suggestion in 1850, it was not until the autumn of 1851 that he published full particulars as to his mode of operation. He then explained how readily collodion flows over a highly polished glass plate, how quickly it sets to a clear gelatinous film, and how satisfactorily it hardens to a transparent and insoluble skin which clings to the glass with the closest cohesion.

All that is required to make collodion is that you should take a given quantity, say 510 grains of pure nitrate of potash in fine powder, 15½ drachms of oil of vitriol and 1½ drachms of water, and stirring them together at a temperature of from 150° to 155° Fahrenheit, add bit by bit 15 grains of cotton wool to each ounce of the acid mixture. Allowing the cotton wool to soak then four or five minutes in this solution, you afterwards extricate it and wash it perfectly clear from the acid. When thoroughly dried, the cotton wool, thus transformed into gun-cotton, is, in the proportion of nine grains of it, mixed with 6 drachms of pure ether and 2 drachms of pure alcohol. Blent in these proportions the gun-cotton dissolves instantaneously. Quite apart from this, an iodising solution is then prepared—iodine by the way having been discovered as recently as in 1812 by M. Courtois—in what at any ordinary temperature presents the appearance of a soft yet brittle greyish black metallic substance that at boiling point evolves a dense vapour, the rich violet hue of which is magnificent.

As simple a recipe as any for the fabrication of the iodising solution, is that of dissolving 12 grains of iodide of potassium, and 4 grains of iodide of cadmium in an ounce of alcohol, the solution thus made keeping readily enough without risk of deterioration until such time as it may be required. A delicate film or cuticle of the iodised collodion having been spread over a plate of glass, the latter is then immersed in a solution of nitrate of silver, under which operation the collodion film becomes coated with a yellowish iodide of silver that is exquisitely sensitive to the actinic influence of light. So sensitive is it, indeed, to that mysterious power, that to secure the latent image it needs no more than an exposure of a very few seconds in the camera—the picture, as yet invisible, being afterwards developed by pouring over the plate either a weak solution of pyrogallic acid, or one of protosulphate of iron, each of which is a powerful reducing agent. When the development of the image has been thus accomplished, whatever iodide of silver yet remains in excess requires instant removal from the plate, as otherwise, under the simple influence of light, it would slowly blacken and thus completely destroy the picture. It is the removal of this surplusage of iodide of silver, in point of fact, which constitutes what is called the fixing of the image. And that feat is accomplished by merely pouring over the plate either a solution of hyposulphite of soda or one of cyanide of potassium.

So rapid was the advance of the photographic art after the discovery by Scott Archer of the application to it of his collodion process, that but little more than a year had elapsed from the date of its announcement when, on the 22nd December, 1852, as many as 774 specimens of photography were exhibited at the Society of Arts. While in the following year, 1853, the London Photographic Society was established, which was not long in existence before it had started the *Photographic Journal.* A couple of years before that, Celestial Photography had been begun in America by Professor Bond, the astronomer of Cambridge, U.S., who publicly exhibited there, in 1851, the first photograph of the Moon ever taken. Half-a-dozen years afterwards—many admirable photographs of the heavenly bodies having been taken in the interval, among others by the late Mr. Warren de la Rue—an apparatus for registering the position of the Sun's spots by a combination of clockwork and photography, was, in 1857, at the suggestion of Sir John Herschel, erected, to the great advantage of astronomic science, at Kew Observatory.

During that same year, 1857, the now familiar Cartes de Visite portraits were first taken at Nice by M. Ferrier. On the 18th July, 1860, Warren de la Rue photographed the darkened disc of the Moon during the crisis of a solar eclipse; and in the following year, 1861, almost more surprisingly a photograph of the bottom of the sea was taken by Mr. Thompson of Weymouth. During the year last mentioned, moreover, the new art was for the first time successfully applied by Mr. John Leighton to the transfer of artistic designs to the wood block, as evidenced by his beautifully illustrated "Lyra Germanica."

Remembering the enormous boon that was conferred upon the world by the discoverer of the means of applying collodion to the development of photography, it can be no matter of wonder that, upon the premature death of both Scott Archer and his wife, a pension on the civil list should have been conferred upon his three orphan children—the only surprise in its regard being that it was one of merely £50 a year. As for the purposes to which this beautiful art of photography has been applied, they are so varied as almost to defy enumeration.

Professor Rood was the one who first suggested, in 1861, the application of the new art to the delineation of the marvels revealed by the microscope. Dr. Henry Wright, again, was the one who in the January of 1863, first thought of giving photographic record of objects of surgical interest. During the spring of 1864 the light of ignited magnesium was first employed for the taking of photographs by Mr. Brothers of Manchester. Photo-Sculpture had already by that time been contrived by M. Villème as a curiously ingenious process for the facilitation of the earlier part at least of the labour devolved upon a sculptor—enabling him, as it does, with the aid of 24 photographs of a model taken through 24 apertures in a circular chamber, to mould a block of clay upon a revolving pedestal by reference, one after another, turn and turn about, to each of these four-and-twenty photographs. Photoglyphic Engraving, again is the title of a process patented by Fox Talbot, by which the light itself, aided by a solution of perchloride of either iron or platinum, actually etches a picture upon a copperplate. Photo-Zincography in like manner is the name of another and kindred process for the delineation by the sunbeam of a printable picture upon zinc, with the help of which cheap maps and charts are produced in abundance. Paul Pretsch's process again of Photo-Galvanography is worthy of passing mention as the art of producing engravings by the combined action of light and electricity. Of this magical art in fact the earliest specimens were those wrought out by Nicéphore Nièpce, and presented by him as far back as in 1827 to Robert Brown the well-known botanist.

Carbon-printing as applied to photography was first employed by M. Poitévin, who adopted with some success a combination of bichromate of potash and gelatine as the vehicle. He thus endeavoured to ensure greater permanence to the photograph. Whatever organic matter, such as gum or gelatine, was blent with the bichromate of potash was coloured by him with lamp-black or some other indestructible pigment. A paper, coated with this mixture and veiled by a negative, underwent some mysterious change in all its exposed parts — solely of course through the actinic action of light—such as rendered the organic matter insoluble. Ingenious as M. Poitévin's notion undoubtedly was, there can be no question that the first really practical application of the carbon process was the one hit upon by Mr. Swan of Newcastle-upon-Tyne.

Johnson's Autotype process grew out of this earlier one some years afterwards, as its most important development. While intermediately between the first announcement of the daguerreotype and the earliest production of the collodion negative — a collodion positive, popularly known as the Ambrotype, and which is still occasionally met with nowadays, long enjoyed a high reputation. It is a picture taken upon a plate of glass previously filmed over with a thin coating of collodion, and in which after a very brief exposure in the camera the lights are represented in silver, the shades being produced by a dark background of black varnish visible through the unsilvered portions of the transparent glass. Similarly there are produced to this day in great abundance minute photographs, variously spoken of as Tintypes and Ferrotypes the collodion image thrown upon which is made directly on thin metal plates previously covered with an ebony-like lacquer or enamel. These, from their extraordinary cheapness and the marvellous rapidity of their production, are likely long to retain their present wide popularity. Cameras provided with a great number of lenses are especially manufactured to facilitate their production.

Numerous preservative or so-called dry-plate collodion processes have been devised for the readier working of photography out of doors, as in the taking of sea-views or landscapes. A curious process contrived by Sir John Herschel, and known as the Cyanotype, yields as its result a photograph which, after being at one stage lavender upon a yellow ground, becomes in the end a blue picture upon a white ground. Another process, also of Sir John's contrivance, and nearly as curious in its way, is termed the Chrysotype. There are besides all this the resin process, and the Fothergill process, as well as the waxed-paper process, the Chromatype, and the Fluorotype. Probably the oldest of all the dry collodion processes was the collodio-albumen process, invented by Dr. Taupenot. What is known as the malt process is generally attributed to Mr. Macnair, the gelatine process having been suggested by Dr. Hill Norris, and the meta-gelatine by Mr. Maxwell Lyte.

To Claude Nièpce de St. Victor (the nephew of Nicéphore Nièpce, the Columbus of photography) the world is indebted for the all but miraculous production in 1850 of veritable Heliochromes—that is to say, photographic pictures in which the objects represented retained their natural colours. They did so, it is true, but fugitively; the natural colours—visible for a brief interval—fading away, and in the end disappearing. Still, for all that, though the light thus retook only too rapidly what it had for a few seconds yielded up, the fact remains that for those few seconds, the natural colours were visible there in the photograph! So that one cannot but still cling to the belief that the time will yet come when the colours will be caught and fixed just as securely as the lights and shades of the picture reflected in the camera upon the sensitised film of collodion.

Professor John William Draper, an English physicist, who died in New York as recently as on the 4th January, 1882, is generally credited with having, in the early part of 1839, taken from the life the very first daguerreotype portrait that was ever produced. Since that marvellous achievement was announced, the magical art of photography has attained, within considerably less than half a century, its now astonishing development. During the interval, the rights of the photographer have been secured in this country; an Act of Parliament having been passed in 1862 for the holding of a copyright in these sun-pictures.

That microscopic photographs are readily produceable was blazoned to the world beyond all possibility of doubt at the time when Paris, in the winter of 1870-71, was beleaguered by the German army. A dot upon a morsel of paper, conveyed into the heart of the French capital under the wing of a carrier pigeon, was then systematically shown, by expansion under the oxy-hydrogen microscope, to contain within it in the form of an elaborate despatch, a very world of intelligence. Upon the other hand it is the easiest thing possible, as every photographer well knows, to enlarge to life-size the merest photographic miniature; and to do this moreover without the necessity of calling to his aid any costly apparatus. An ordinary carte de visite may, in fact, by a simple re-adjustment of the usual appliances,

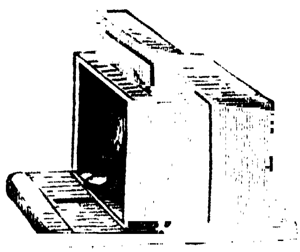

Fig. 52.—Ground-Glass Plate at back of Camera.

be magnified to almost any dimensions. How easily this may be accomplished may be understood upon the instant when it is borne in mind that the nearer the camera is to the object which has to be photographed, the larger will be the image produced, and that on the contrary, the further from the object the camera is removed, the more is the image of that object diminished. Whenever a large image of a sitter is required, for example, the camera is extended. And *vice versâ*, whenever a small one is aimed at, the camera is shortened—in either case the image being so focussed that its outlines are shown perfectly clear and sharp on the ground glass which, until the moment arrives for the taking of the photograph, occupies the place of the clear glass filmed over with collodion. Enlarged photographs, by the way, may be produced either rapidly by direct sunlight, or slowly by diffused daylight. They may even be obtained by the agency of

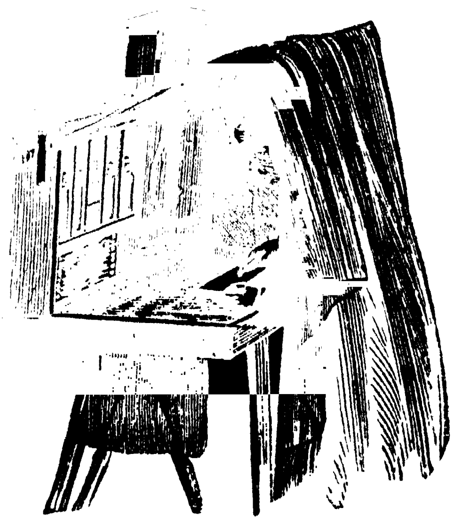

Fig. 53.—Dark Curtained Tent for Out door Photography.

artificial light, the most powerful of which class in its actinic effect is notoriously that of magnesium.

So instantaneously may photographs be now taken, that not merely moving figures, but rapidly moving figures—flying clouds, rolling waves, fluttering leaves, skaters skimming over the ice, horses at full gallop, an express train whirling past at its utmost speed—may be caught in the twinkling of an eye upon the sensitised plate by a simple adjustment of what are known as instantaneous shutters. Providing only the chemicals employed are in good condition (bromo-iodised collodion usually producing the best results), the lenses thoroughly good, the sunshine brilliant, and the subject under treatment suitable, the happiest effects are arrived at. And this, too, by an exposure of hardly measurable duration, the merest infinitesimal part of a second!

A wonderfully ingenious system in fact has been contrived by Mr. Muybridge of California for the photographing thus, at full swing, of men while they are in the very act of walking or running, and of horses when trotting, cantering, leaping, caracoling, or careering at full gallop. His plan is simply this: that the person or animal about to be photographed has to pass—it matters not at how wild a pace—in front of a long photographic apparatus containing in front of it four-and-twenty distinct lenses, which are instantaneously opened in rapid sequence by the snapping of as many fine threads either laid upon the ground, or stretched across in mid-air. So perfect are the results produced by this arrangement, that when these four-and-twenty photographs are placed in due succession round a zoetrope or wheel of life, upon the latter being whirled round swiftly within range of the lens of a magic lantern, the men and horses are seen again there, in actual movement, just as the case may happen to have been with them—walking, running, leaping, trotting, or galloping.

Photographic cameras of very different kinds are

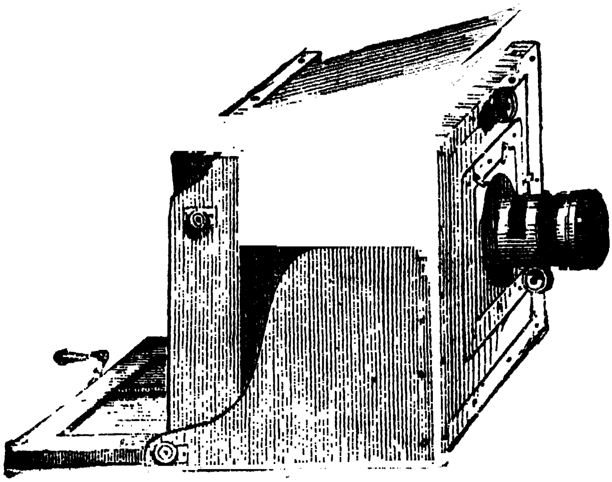

Fig. 54.—Bellows-shaped Camera: Front View.

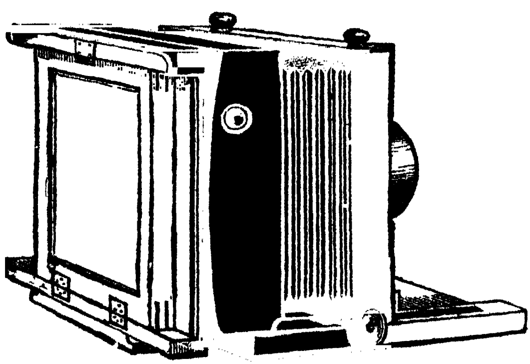

Fig. 55.—Back View.

constructed, the one in ordinary use resembling a couple of boxes of nearly the same size; the smaller one sliding inside the other. Another kind, known as the bellows-bodied camera, has an expansible portion, exactly like that of an accordeon; its compactness, when closed, being greatly to the good in travelling. The Stereoscopic Camera, besides having two lenses, contains a binary chamber. While in addition to these, there are not only the solar camera, but cameras for

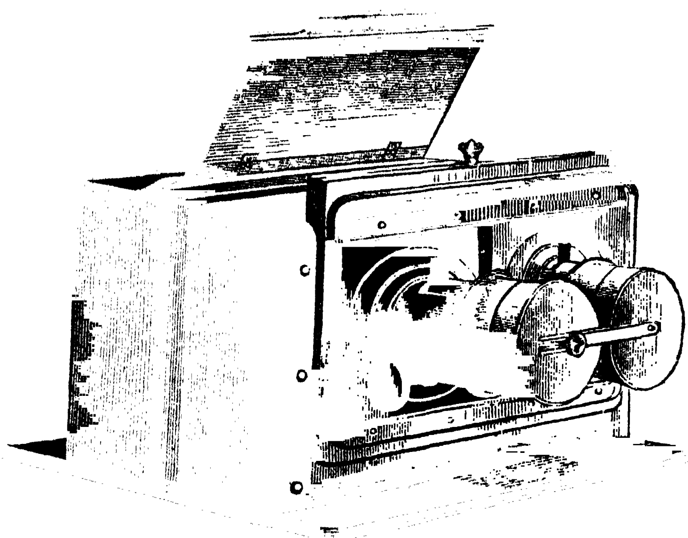

Fig. 56.—Stereoscopic Camera.

the field and for the studio, for copying and for enlarging. Provided with whatever camera and lens may happen to be most suitable for his immediate purpose, the photographer has next to see that both the lens-holder in the front and the plate-holder at the back are in proper condition, and that there is a perfectly glib and free movement of the rack-adjustment for focussing. A camera-stand is his next essential, together with a chair having a vertically adjustable back, and a head-rest having readily adaptable and extensible rods for the posing of the sitter in any required attitude. Adjoining the room in which the sitter is posed in front of the camera, and where the photograph therefore is taken in little more than a few beats of the pendulum, the photographer requires to have a darkened chamber dimly illuminated with yellow, every particle of white light being carefully excluded. This is accomplished by having the window of this little neighbouring apartment glazed with a deep orange-coloured glass, the light passing through which, exercises no appreciable chemical action whatever upon the sensitive chemicals employed in the manipulation of the photographic art.

Thus provided with a proper place of retirement for his subtler operations, the photographer gathers about him there an ample supply of the materials and paraphernalia essential to his calling. Foremost among these are five all-important chemicals—nitrate of silver, odized collodion, proto-sulphate of iron, acetic acid, and cyanide of potassium. Without the aid of these in due sequence and in proper proportion, and without in addition to them patent glass plates of various sizes, he would be as helpless as a magician without his wand and his attendant sprites. Supplementing even these he will require, among other miscellaneous items, a dipping bath and dipper for the nitrate of silver solution, a focussing curtain of either black cloth or black velvet for the back of the camera, two or three glass measures and funnels and a few dishes of porcelain, together with spirits of wine, filtering paper, and black and white varnish.

Everything having been got thus in readiness for the

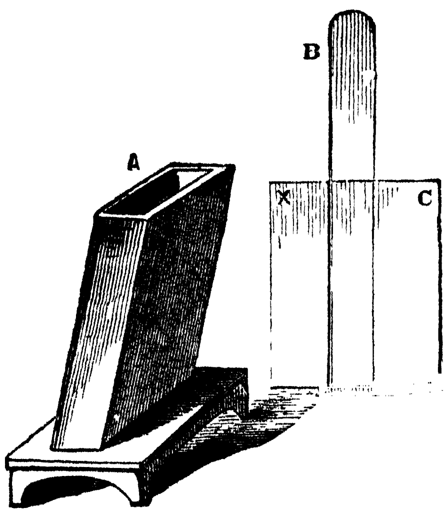

Fig. 57.—A Dipper-Bath and Dipper.

production of a photograph, a suitable sheet of patent plate-glass is selected by the operator, who first of all thoroughly cleanses it by friction with the help of rotten-stone and alcohol. Holding it horizontally then by the top right corner, between his left hand forefinger and thumb, the manipulator pours on to the middle of the glass plate, until it is nearly half-covered, a supply of iodized collodion. Retaining in his right hand the bottle from which this supply has been taken, he then gently tilts the plate in his left hand so that the collodion runs toward the thumb by which the plate is held, without however allowing his thumb to be touched by the liquid. Next he so inclines the plate that the collodion runs from A to B, from B immediately afterwards to C, and finally on to D; from which last mentioned corner of the plate any excess of collodion is poured back again into the bottle.

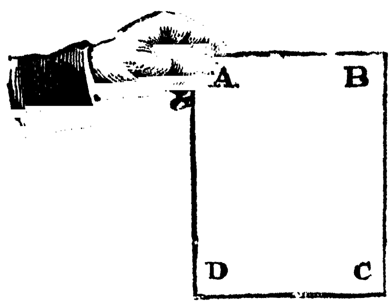

Fig. 58.—The Glass Plate held between Finger and Thumb.

Thus applied to the burnished glass-plate, the iodized collodion spreads over it in a thin film, like varnish, which setting in a minute or two, hardens there into a tough and tenacious skin or cuticle. Before the setting has commenced, however, the plate, held in an upright position is gently rocked to and fro by the operator, so that any ridges or inequalities in it are thereby effectually smoothed away.

A silver bath having been previously prepared in which an ounce of pure crystallized nitrate of silver is dissolved in sixteen ounces of distilled water, the mixture being afterwards well filtered, the collodionized plate is immersed in that silver bath and left there for awhile. Containing, as the collodion used in photography does, certain important metallic iodides and bromides (usually those of potassium, ammonium, or cadmium), these latter, combining with the silver in the nitrate of silver bath during the period of immersion, form all together a film which is wonderfully sensitive to the action of light. A transformation occurs in the gelatinous film of the collodion during this interval, consequent upon which metallic silver takes the place of the alkaline and other metals in the film or cuticle, forming, there, in point of fact, insoluble bromide and iodide of silver.

Under the influence of the change thus wrought in the tough coating of the glass plate, it (the coating) ceases to be transparent and becomes instead of that milky or clouded. Having been thus sensitised, the plate—so soon as the solution is seen to run off it in an even sheet instead of in greasy lines or rivulets—is thoroughly drained, first, while resting on the dipper and afterwards while resting on a sheet of blotting paper. It is then placed face downwards in the dark slide of the plate-holder in which its corners rest upon supports especially provided for their reception. Thus veiled from the light, it is conveyed from the dark chamber or developing closet to the photographic camera, which in the meanwhile at a distance of eight feet from the sitter has been duly arranged and focussed. This adjustment, by the way, has been made just before by the photographer at the back of the instrument when, with his head concealed under the focussing curtain, he has drawn the sliding body of the camera out until the image thrown by the lens on the ground-glass appears with tolerable distinctness—the exact focus being then obtained by means of the rack and pinion attached to the lens. As a rule the plan is to focus for the eyes, turning the pinion now one way, now the other, until the eyes are clearly and sharply defined.

Returning to the back of the camera, the operator now duly armed with the plate-holder, substitutes the latter for the ground glass, and having done so pulls up the sliding door or flap, which until that moment has covered the glass plate filmed over on the side towards the lens with the sensitised collodion. A quiet word having then been given to the sitter, such as "Now," so that he or she shall be on the alert or otherwise motionless during the critical moments, the brass cap is removed from the front of the lens, the plate being exposed thus for a few seconds to receive the image exactly as it had before fallen on the ground-glass panel at the back of the instrument. A sufficient interval being elapsed, measured out by the watch of the photographer, the cap is replaced on the lens and the sliding door or flap is dropped again upon the plate-holder, which is then taken back into the dark room for the next stage of the process, that of development.

Although the rays of light have already, during the plate's brief interval of exposure in the camera, effected a mysterious change of some kind (whether chemical or physical is still matter of dispute) in the very substance of the sensitised film of collodion upon which the image has fallen between the removal and the replacement of the cap of the lens, no apparent alteration of any sort has taken place when the plate is first extricated, in the darkened chamber from the plate-holder. Immediately, however, that there is poured over its surface an aqueous developing solution, composed of a salt of iron, generally speaking the protosulphate of iron, with which a certain proportion of acetic acid has been mingled, the hidden picture instantaneously becomes apparent. A skilled photographer usually contrives by a dexterous movement to cause this solution to flow over the plate in one wave without intermission. So soon as the image, which at once starts to view has become perfectly clear, the developing solution is thoroughly washed off the plate with plenty of water, by which means its further action is effectually arrested.

As the next step in this wonderful process, the picture thus revealed is fixed or rendered permanent by flooding over it a solvent of the silver salts; this fixing solution being either diluted hyposulphite of soda or cyanide of potassium. Through its agency the milky aspect of the deposit given to the film by the negative bath is entirely removed, the sun-picture thenceforth resting magically to all appearance on the bare glass like a transparency. When once the soluble portions of the film, however, have been dissolved by the fixing solution, the latter must in its turn be as quickly as possible washed away, lest its potent agency may act injuriously upon the negative which has been thus developed. When it has been thoroughly drained and dried, it is then carefully varnished with a resinous solution that is perfectly clear and crystalline. Having reached this stage the collodion Negative is in a condition to be used for the printing off, in any number, of Positive Photographs.

Strictly speaking, as already explained, a collodion negative is really no picture at all. Far better than that, however, it is a product of the marvellous art I have been here describing, from which may be obtained with the greatest ease an absolutely indefinite number of photographic impressions. Delicately traced though it is upon glass, it has—by right of its being beyond the reach of deterioration except by fracture—a distinct advantage over a wood block or a steel or copperplate engraving. For, whereas the latter may be worn out by overmuch printing, the collodion negative, printing as it does by the agency of light alone, which has no longer any alterative influence upon itself, passes scathless through the operation.

How it is that positive photographs may be readily printed from the collodion negative, a very few words here will suffice to explain. A piece of ordinary writing-paper is soaked in a solution containing some soluble chloride, such as chloride of sodium, that is common salt, or chloride of ammonium. Having been well dried, the paper thus impregnated with brine is floated upon a solution of nitrate of silver. Hereupon there is formed in and on the paper—chloride of silver, the extraordinary sensitiveness of which to light is such that supposing the paper were now freely exposed to the daylight it would all of it very rapidly become blackened. Paper thus sensitised is the material upon which the positive photograph is produced by placing it, the paper that is, under and in close contact with the collodion negative in broad daylight. An exceedingly shallow quadrangular box, called variously a printing frame and a pressure frame, and in shape not very much unlike a small shaving-glass, has been constructed for the purpose of bringing the negative and the sensitised paper in a well compacted way together at the time of exposure. This printing frame, which opens at the back while it is provided in front with a plate of glass, having been duly opened is placed face downwards on a table. It has then first of all laid nside it the negative, on the top of which is put the sensitised paper. Thereupon the back of the frame being shut down is kept firmly in its place by certain springs or buttons. Thus securely fastened, the printing frame is turned face upwards, its well flattened contents being thereby fully exposed to the daylight. As the result of this, the light passing through the negative soon begins to produce a darkening influence upon so much of the

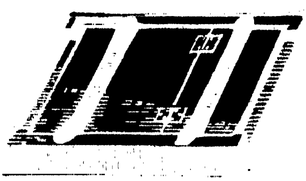

Fig. 59. The Printing or Pressure Frame, with Springs.

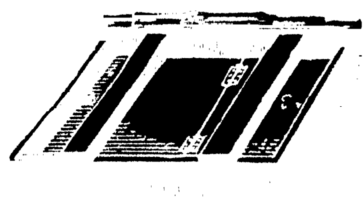

Fig. 60.—Printing or Pressure-Frame, with Buttons.

sensitised paper as is revealed. Not however until its colour has ripened to a dark reddish brown and has become almost black in the deepest shadows is it evident that its exposure has been sufficiently prolonged. But so soon as those richer hues have been attained, the paper, released from the pressure frame, is washed plentifully with water, so as to hasten the removal from it of whatever free nitrate is remaining. Toned with an aqueous solution in which chloride of gold and acetate of soda are the ingredients, the photographic picture becomes from that moment at once more pleasing and permanent. Having been then rinsed in a dish of perfectly clean water, the image upon it is fixed by its immersion for a quarter of an hour in a bath of hyposulphite of soda. Finally, in order to cleanse from it every vestige of this last-mentioned powerful agent, any trace of which, if allowed to remain, would later on, oddly enough, cause the image gradually to fade away, the print is for six hours together thoroughly washed anew in four or five changes of translucent water: after which it is mounted, either with starch paste, or better still with freshly made clear glue, upon cardboard. When dry, the finished photograph is calendered with a rolling-press, by which completing process it has imparted to it a perfectly flat and glossy surface.

Thus reproduced again and again with the readiest ease, it is for all the world as if by the magic art of photography the pictures of the camera could not only be caught and perpetuated upon the glass slide as upon a solid slice of air, but as if they could be afterwards shredded off in countless flakes that are showered around us, thick as leaves in Vallombrosa.

IV.—THE SEWING MACHINE.

"Stitch, stitch, stitch."—THOMAS HOOD.

SINCE the famous search began more than three hundred years ago for Gammer Gurton's Needle—as related in the queer old comedy of that name written by Bishop Still when he was a hare-brained young Master of Arts, and first acted in 1566 at Christ Church, Cambridge, before Queen Elizabeth—no such memorable quest of that homely implement has ever been heard of as the one which, for nearly ninety years together, from about the middle of the eighteenth century exercised the wits of a long succession of the most ingenious inventors in both hemispheres.

What each of these in turn deliberately set himself to accomplish, was the construction of a piece of mechanism capable of wielding a needle and thread with a rapidity, a precision and a rhythmic symmetry of movement entirely beyond the reach of any merely human manipulation.

Nothing more was effected at the outset by what must be regarded as the first rude germ of the sewing machine, than the production of a simple running stitch with the aid of such primitive appliances as an ordinary needle and a mere needleful of thread. A distinct step in advance was made shortly after this, however, when on the 24th June, 1755, a patent for an embroidering machine was taken out in London by a mechanic apparently of German origin, named Charles Weisenthal. A needle, pointed at each end and having its eye in the middle, was the thread-carrier employed by him in this clever contrivance, which was designed partly no doubt for the imitation of hand-sewing, but more especially, as its very title indicated, for the purposes of embroidery.

Another contrivance—which is reputed by some to have been the first application of machinery to the production of needle-work—was patented in England on the 22nd March, 1770, by Robert Alsop, whose loom succeeded in embroidering, with the aid of a variable number of shuttles.

Satisfactory to a certain extent though these earlier efforts may for the moment have appeared, they were only too soon found to be absolutely valueless. For neither the short-thread machine, nor yet the double-pointed needle machine, when put to the test, proved able to do, even in a bungling way, much less glibly the work either of the tailor or of the sempstress.

Thirty-five years, however, after Charles Weisenthal's invention had been made public, an entirely different patent was taken out, on the 17th July, 1790, by one Thomas Saint, also of London, for quilting, stitching and sewing, as well as for the making of shoes and other articles by means of tools and machines. Nearly a hundred years have now elapsed since the drawing out of that specification. Yet, wonderful to tell, even then more than half a century before the first really practical automatic Sewing Machine was fabricated, many of the chief integral portions of the coming masterpiece were in Thomas Saint's invention distinctly foreshadowed.

There, at the very heart of the contrivance, for instance, placed upon a support like a miniature table, was the horizontal clothplate. There, again, planted perpendicularly near that fixture—rooted securely in the bed-plate sustaining both—was an upright post from the summit of which projected, at right angles to it, an over-hanging beam, or gallows-like protrusion Immediately below the extremity of this out-stretched arm—resting exactly beneath it upon the miniature table just referred to—was the box supporting whatever material it was proposed to sew, stitch, or quilt with the aid of a thread-carrying needle worked from above by a purely mechanical combination of forces. This straight needle, besides, which descended vertically, was what is termed reciprocating in its action, meaning that it was thrust down and drawn up again in rapid sequence as with a swift succession of stabs and withdrawals, from the lower part of the overhanging arm before mentioned.

Midway upon the upper surface of that protruding beam, moreover, was a spool or hollow cylinder from which was unwound the thread, continuously supplying the needle as it rose and fell. Falling and rising in momentary alternation with the needle, and exactly parallel to it, was a tiny awl which, each instant, pointedly prepared the way for the needle's descent directly afterwards. The awl in fact pierced a minute hole in the cloth or leather brought under its operation, into which hole the needle, notched at its lower extremity, thrust the thread, which latter upon the needle's withdrawal was left in a loop on the under surface of the material—each successive loop being interchained with its immediate predecessor. Meanwhile, in exact proportion to the throbbing downwards of the pointed awl and the notched needle, there came —intermediately, at a stitch length, between the descent of the two—an intermittent feed of the cloth or leather beneath, thereby securing the steady and symmetrical completion of the chain stitch which was thus being wrought out above and below the goods by thread-tightners. Simultaneously with all this, the thread-tightening, in its turn also, was secured, as with the regularity of a pendulum's beat, above and below, by means of a spindle which reached downwards from the protruding beam at a point about equidistant between the thread-spool and the needle and awl carriers. These latter, it may be added, were kept in rapidly alternating descent by the revolution of a cam, meaning one of those revolving distorted disks so fixed upon a shaft as to impart to a rod or lever in contact with it any variable motion at any required velocity. During the lifetime of two whole generations, Saint's marvellous contrivance was so entirely lost sight of that when, at the close of that long interval, it came at length to be virtually disentombed, it was regarded by everyone who examined it with about equal amazement and admiration.

Whatever else the fabricator of this wonderful piece of mechanism may have been, he was beyond all dispute a man distinctly before his time. Seemingly all but by intuition, he, as far back as in 1790, hit upon the first of the three great essentials of the Sewing Machine, to wit, the Continuous Thread—doing so forty years before the discovery of the second, that of the Eye-pointed Needle—and sixty before the discovery of the third, that of the Continuous Feed. Overlooked and almost forgotten until the two later of those paramount discoveries were made by the man whose merit it is to have first brought all three into combination, Thomas

Saint, though we know nothing more of him to-day than his name and the particulars of his invention, is exceptionally noteworthy as having been the direct precursor of Elias Howe, who was to the Sewing Machine what James Watt was to the Steam Engine, that is to say, beyond all manner of doubt or comparison, its chief inventor and perfecter.

Prior to the advent of this supreme contriver of the Sewing Machine, many attempts, some of them remarkable for their ingenuity, had been made to bring about in some way the production of needlework by machinery. Fourteen years after Saint's patent had been signed and sealed, another of a less comprehensive character was granted, on the 30th May, 1804, to John Duncan—the principal merit of which was that it led the way to the first glimmering notion of an eye-pointed needle. Whatever cloth or what not was placed in this machine for piecing together was stretched, smooth and taut, between a couple of cylinders fixed, at a sufficient distance apart and parallel to each other, in a wooden frame which was capable of moving horizontally in another frame so that the material under treatment could at pleasure be brought into any desired position, oblique, horizontal or perpendicular. A number of crochet needles being then driven downwards through the cloth, each of these in turn was supplied with thread, upon the other side of the fabric, by a feeding needle which passed the filament under and around the barb by a slight but sufficient deflection. Consequent upon this, each hooked needle, upon being withdrawn, drew back with it a loop which passed upwards through the centre of the one previously caught up when the needle had last receded. Scarcely three years had run out after Duncan's invention had been announced, when, in 1807, letters patent were accorded to James Winter for certain improvements in sewing machinery. These in 1821, were materially added to by their inventor—both patents, however, having relation almost exclusively, to the facilitating of the hand-sewing of leather gloves: that is, by the application of metal clamps, for the better holding of the materials in position, and of metal grooves for the better guiding into its appointed stitch-holes of the needle plied by the artificer.

Five years after the date last mentioned, a patent, also for sewing leather, was taken out on the 10th of March, 1826, upon the other side of the Atlantic, by Henry Lye of Philadelphia. No particulars as to the nature of this invention, however, are nowadays anywhere procurable, the patent records of the United States down to 1836 having been destroyed in that year by a disastrous conflagration.

An embroidering machine of a novel kind meanwhile had, on the 2nd May, 1829, been patented in

England by a German inventor named Heilmann, its speciality being this, that it was worked by a hundred and fifty double-pointed tambour needles, which were simultaneously set in motion upon a moveable web of cloth, each needle repeating its appointed pattern, now here, now there, precisely as the gold and silver threads upon a silken tambour-frame are woven at regular intervals, under the hand of a skilled tambour-woıker, into any pre-arranged device of flowers and foliage.

A twelvemonth after the completion of this ingenious contrivance, a patent was taken out, in Paris, on the 17th July, 1830, by Barthélemy Thimonier, for sewing cloth together by machinery. In more than one particular the arrangements combined in this invention resembled those employed by Heilmann in his device for the mechanical production of embroidery. Alike in each, the thread-carrier lay in wait under the woven fabric. Similarly in each a crotchet needle, descending through the cloth, caught up a loop of thread which in its withdrawal upwards was enchained with the one just before dragged to the surface, and so on successively. Immensely enhancing the value of these arrangements, the French inventor introduced in this patent the first presser-foot ever employed in the fabrication of a Sewing Machine. Allusion is here made to that now familiar little foot-plate which rests upon the cloth while the needle with bewildering velocity is probing it and being retracted.

For several years Thimonier's contrivance, in spite of all its shortcomings, was steadily worked by him at Paris in the stitching together of army clothing. It was so utilized, however, it should be remarked, under enormous difficulties. Eleven years after the inventor's rights had been secured by the State, his enterprise was so far successful that eighty of his machines were in full work, making infantry uniforms at his Paris establishment. Thereupon, an outbreak on the part of the journeymen tailors of the French capital, did by this Sewing Machine of Thimonier just as the infuriated rabble of Lancashire had done at the beginning of the century by the spinning jennies of Hargreaves, and as those of Lyons towards the close of the eighteenth century had done by the figure-working looms of Jacquard.

It is of this last-mentioned inventor—Joseph Jacquard, the straw-hat manufacturer of Lyons—that a whimsical but profane story is told. Namely, that—upon his being summoned to Paris by order of Napoleon the Great, (to see whether he, as the contriver of the wonderful net-making machine, might not just possibly succeed in improving upon the only half-efficient looms then belonging to the government)—Carnot, the famous War Minister who, during the more critical days of the Revolution had won for himself the sobriquet of the Organiser of Victory, grandfather of the Fourth President of the Third French Republic, brusquely welcomed his entrance into the ministerial cabinet with the enquiry, "Are you the man who can do what the Supreme Being cannot: tie a knot on a stretched string?"

Mustering in rather larger numbers than "the four-and-twenty tailors" who, once upon a time, according to the old nursery ballad, "went to kill a snail," the knights of the goose and thimble at Paris, in 1841, completely wrecked Thimonier's factory from garret to basement, destroying the whole of his machinery, and only by the merest hairsbreadth allowing the inventor himself to escape with his life. Notwithstanding this, so indomitable was his courage and perseverance, that seven years afterwards the invention, which he had brought to light in the midst of the Revolution of 1830 was once more found, upon the outbreak of the Revolution of 1848, to be in a highly prosperous and flourishing condition, sewing and embroidering almost any material from crape to huckaback, at the rate of 200 stitches a minute. Again, however, an ignorant mob of journeymen carried everything before them, smashing the machines (which were constructed almost entirely of timber) into so much matchwood, and for a second time seriously imperilling the person of their fabricator.

Before another interval of ten years had elapsed from the date of his second patent, which was secured on the 5th August, 1848, Thimonier, in 1857, by reason of all this, died in absolute destitution.

Fifteen years prior to that, on the 21st February, 1842, John Greenough of Washington had patented a contrivance for effecting by machinery the through and through or shoemaker's stitch, with the help not merely of a needle pointed at both ends and having its eye in the middle, but of an implement of that kind so aided in its operations by a pair of clamps above and below the fabric, that it was pushed through on the one side and drawn through on the other in a manner distinctly imitative of the driving thimble and the plucking finger and thumb of the tailor, or of the sempstress.

Within the time during which Barthélemy Thimonier was vainly striving to win his way in spite of his persecutors, another human history very much akin to his, was running its course in the United States, and for awhile also in the United Kingdom. Long threatening to have an equally disastrous close, it was happily rewarded in the end with both fame and fortune.

Elias Howe—whose pre-eminence among the inventors of the Sewing Machine is for all the world like that of Gulliver among the Lilliputians—was born on the 9th July, 1819, at Spencer, in Massachusetts. Until he was sixteen years of age he lived at home with his father, who was both a farmer and a miller. During the spring, summer, and autumn of the last five or six of those years, he worked steadily in turn among the paternal hinds on the farm and at the grist mill, attending the district schools industriously all through the dead winter season. Yielding at length to the promptings of his own nature, he announced in 1835, as a mere stripling, that his choice was made to be what is termed in America "a machinist." Going in the first instance to Lowell, he there, to begin with, obtained employment in one of the establishments where cotton machinery is manufactured. Thence after a few years he went to Boston where, in the Cornhill of that city, having worked for a while in the machine factory of Ari Davis, the inventor of a most ingenious mechanical arrangement for dove-tailing, Howe settled down at last in earnest to what was from that date onward to be the one great business of his life—the mastering of an idea which from his earliest manhood upwards had completely seized upon his imagination. He appears in fact to have been barely twenty-one years of age,—by which period he was already married though his earnings at that time were no more than nine dollars a week—when he first conceived the notion that it might be possible for him some day to construct a thoroughly practical automatic Sewing Machine.

That dominant idea, which ruled all the rest of his existence, seems to have been originally suggested to him by a chance remark he overheard one day in the workshop of his employer, Ari Davis, in the course of

Fig. 61.—Elias Howe.

an animated discussion between a Mechanic and a Capitalist, the former of whom had just brought to the latter, for his inspection, a partially successful machine for knitting, of his (the Mechanic's) construction. Suddenly interrupting the interlocutors, Davis almost indignantly enquired, "What are you bothering yourselves with a knitting machine for? Why don't you make a Sewing Machine?" "I wish I could," said the Mechanic, "but it can't be done!" "Oh yes, it can," cried Davis, "I could make one myself." "Well," was the Capitalist's remark, "you do it, Davis, and I'll insure you an independent fortune." Spoken at random, those words were like good seed falling upon good ground, dropped as they were in the hearing of the curly-headed under-sized stripling, who, six years afterwards, himself realized the boast of Ari Davis, and who nine years after that began far more than merely to fulfil the prediction of the Capitalist.

Thenceforth, for five years together, he gave himself up, body and mind, in all the intervals of his toil as a factory hand, to the pursuit of a fancy that was regarded by the majority of those who knew anything at all of what he was about, as the wildest craze imaginable—the endeavour, that is, to work out to a solution a problem which even the more sagacious of his contemporaries, down almost to the close of his labours, had come to look upon as insoluble.

Instantaneously one day, in the midst of his meditations, the thought startled him—Need the machine, after all, imitate the movements of the fingers? Might not there possibly be a different and yet an equally effective stitch? Following up these reflections, the notion occurred to him that with the help of two threads instead of one the design arrived at might be effectually accomplished. To bring these two auxiliary threads into play, he thought first of the Curved Eye-pointed Needle, and in the next place of the aërial Shuttle. By the October of 1844, he had made clear to himself with a rude model made of such rough materials as wood and wire, that a Sewing Machine such as he was now dreaming of, might be readily enough manufactured.

Fixing his thoughts thus upon his self-appointed task at every possible opportunity in the midst of his daily grind as a handicraftsman, Howe at length, by the December of that year, saw his way so clearly to the realization of his long cherished day-dream, that he determined not only to quit Boston but at the same time to abandon all his usual avocations—so that he might in point of fact, from that time forward, give himself up entirely to his one all-mastering enterprise. Having resolutely made up his mind to this new course of life, he thereupon took possession of a particularly small, low garret in the house of one Mr. George Fisher, a newspaper publisher and coal merchant, in Cambridgeport, Massachusetts. Shutting himself up there in complete seclusion, Elias Howe applied his subtle intellect and his supple hands, early and late, to the imparting of the last finishing touches to his marvellous little piece of mechanism. Four months of intense application brought to him at length his long-looked-for reward.

In the April of 1845, the young inventor, being then just twenty-six years of age, by sewing a seam with his contrivance, vanquished his last mechanical difficulty in his garret at Cambridgeport. Emerging from it, he brought out with him perfect and entire—the work of his own brain and the work of his own hands—a Sewing Machine which, in obedience to the turning of a handle, ran off, with mathematical accuracy and with dazzling rapidity, 150 lock-stitches in half a minute: an average of 30 stitches in exactly double that time being alone possible by means of hand-sewing!

With that earliest constructed of all sewing-machines—which is still preserved intact at No. 28, Union Square, New York, and which is a very small piece of mechanism—a couple of suits of clothes of the finest broadcloth were with astonishing swiftness put together in the July of 1845, one of which was worn by the inventor himself, and the other by the owner of the garret, who, for giving the man of genius food and shelter there for less than half a year, secured to himself, in return for a nominal sum of 500 dollars, one moiety of this extraordinary invention. Consequent upon that rather hard bargain, a patent was taken out on the 10th September, 1846, in their joint names as the owners of this latest World Wonder. "Thus," as the familiar words run, "bad begins, but worse remains behind." Eleven days after the patent had been granted to him for his magical contrivance, Elias Howe, driven by necessity, had no alternative but, in return for a nominal sum of

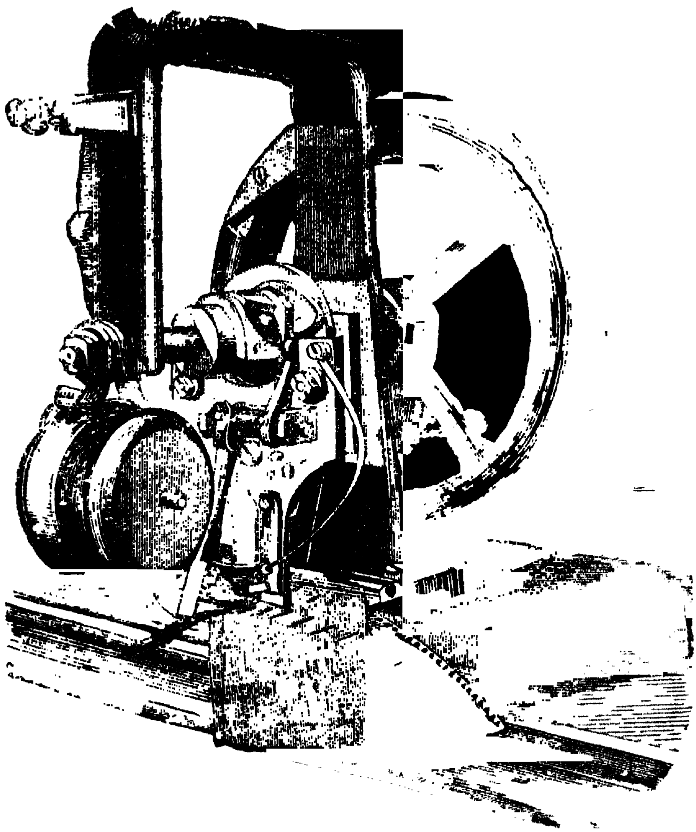

Fig. 62.—The First Sewing Machine.

$1000, to assign the other half of his property in it to his father, in satisfaction of the latter's claims upon him for certain small loans of money, and for so much, or rather it ought more correctly to be said, for so little board and lodging!

Thus, upon the very morrow of the completion of his invention, Howe found himself completely stripped of any chance of securing in the United States themselves, the smallest advantage from its adoption. For a while he was driven to such straits in point of fact, that he obtained employment for an interval as an Engine-driver on one of the railroads—day after day, for many weeks together, taking charge of his locomotive.

Alarmed lest he might otherwise fail to reap any further benefit from it whatever, Elias Howe despatched his brother Amasa at once to England to see after his interests in connection with the patent in that country. Thither, in the February of 1847, he himself followed; being followed in his turn a little later by his wife and his three children—Amasa having meanwhile parted with the whole of the inventor's rights in the English patent for the modest sum of £250 paid down for them by Mr. William Thomas, a corset manufacturer of Cheapside, in the city of London. Apart from that paltry sum, and a verbal promise which was never fulfilled that the purchaser would pay to the inventor three pounds for every machine that was sold, the only lure held out to Elias Howe as an inducement to him to cross the Atlantic, had been the proffered payment to him of a weekly wage of £3 sterling, in return for which the contriver of the Sewing Machine actually came all the way from the new world to the old merely to adapt his wonderful contrivance to the petty requirements of the London stay-manufacturer! When those requirements were satisfied the £3 a week ceased, Howe being then left, in a strange land, completely to his own resources. During the rest of his sojourn in England, which lengthened out to some two years altogether, the inventor was driven to the direst straits, being at one time even thrown into a debtor's prison. Eventually, however, though not until after he had run the gauntlet of a long series of humiliations, he contrived to obtain his passage back to America—landing at New York, before the close of 1849, in a state of complete destitution. Upon the very day after his arrival he resumed his old labours as a journeyman machinist. His cup of affliction was not yet drunk to the dregs, however; for, only a very few days after he had settled down to work, he was hurriedly summoned home to Cambridgeport by, the news of his wife's alarming illness from consumption. Hastening thither upon the instant, he had the grief of seeing her die in his arms before the close of another fortnight.

Removing shortly after this great home sorrow to Roxburgh in Massachusetts, Elias Howe for four years together, from 1850 to 1853, each inclusive, was engaged in a series of expensive lawsuits against a multitude of persons in various parts of the States who were openly and in the most flagrant manner infringing the rights of his invention. At length, however, in the year last mentioned, at the close of one of these same lawsuits—a crucial one involving more or less the whole of the numerous questions which had been so long in dispute—the verdict was given emphatically in favour of Elias Howe after a trial of no less than three weeks' duration. Judge Sprague of Massachusetts, who adjudicated upon the occasion, decided that the plaintiff's claim was valid, and that the defendant's machine was an infringement. Further than that he insisted in so many words that there was no evidence in this case leaving a shadow of doubt that for all the benefit conferred upon the public by the introduction of a Sewing Machine the public was indebted to Elias Howe.

That decision was the signal for him of a new and most happy departure. On the 18th May, 1853, there was accorded to him full power to grant licenses, of which within six years from that date he had actually issued over 130,000, yielding him a net return of more than $400,000. Meanwhile, before half that interval had elapsed, he had, on the 1st October, 1855, by the purchase of all out-standing claims, become once more in the United States the sole owner of his patent for the Automatic Sewing Machine. His income from it thenceforth steadily increased until it soon reached an annual sum of $200,000.

When the American civil war broke out the famous inventor of the Sewing Machine was enlisted as a private soldier in one of the Connecticut regiments: in connection with which circumstance it is mentioned in his regard, as illustrating at once the affluence and the patriotism of the once poverty-stricken man of genius, that when the payment of the regiment had been for some time delayed by the government, Private Howe out of his full coffers freely advanced the necessary money.

Shortly after the completion of his forty-eighth year, the inventor of the Sewing Machine was decorated with the Cross of the Legion of Honour by the Emperor Napoleon III. But, ten years later, Elias Howe's eventually prosperous career was closed rather prematurely by his death on the 3rd October, 1867, in Brooklyn, the fortune realised by him down to that date being estimated in round numbers at $2,000,000.

As already intimated, the claimants to the honour of having invented the Sewing Machine are very numerous —the mere patentees who have originated improvements being a bewildering multitude. Four distinct kinds of Sewing Machines have at different times been constructed. Of these the earliest and least effective class, it should be remembered, was the one (no longer now in use) in which the needle was made to pass completely through the material as in hand working. Another, the second class, was that in which the chain stitch was wrought out by the crochet needle. A third was that in which, while a fair stitch was made on one side, the upper thread was interwoven by another thread below, a twisted loop-stitch also being thereby produced. Finally, as the fourth and most perfect class of all—the first in merit, the last in time, the best in quality—there is the now universally well known and highly prized Lock-Stitch Sewing Machine.

Certain shadowy claims have been advanced which would accord to Walter Hunt of New York the credit of having in 1834 suggested the root-idea of the Sewing Machine last mentioned. Experimental attempts were no doubt made by him in the year just named to produce a working model (which, however, never worked) combining in it a curved eye-pointed needle fixed at the end of a vibrating bar, and a shuttle designed to make (what nevertheless it never did make) the particular stitch now known as the lock stitch.

Eight or nine years after Walter Hunt had entirely abandoned his futile endeavour to transform a half-shaped theory into a perfect automaton, Elias Howe—knowing nothing at all about his predecessor's abortive experiments—began quite independently to put together his wonderful little piece of mechanism. So independently, and more than that, so triumphantly did he work upon it until the first Automatic, Lock Stitch, seam-forming Sewing Machine was perfected by him in his garret at Cambridgeport, that he is now universally accredited throughout the world as its undoubted originator.

Elias Howe's Sewing Machine was, in the fullest sense of the words, what it affected to be, namely, a piece of mechanism for making stitches and interlocking threads, for putting a tension upon the thread, and for drawing up and duly securing each individual stitch. Its needle was curved, grooved, and eye-pointed. Further than that, it was carried upon the end of a vibrating arm Passing its eye-point through the cloth, it, in the very act of being retracted, formed a loop through which another thread was shot by a flying shuttle.

As worked in the original machine, that of 1846, the needle moved in a horizontal direction; the cloth being held vertically by pins protruding from a thin steel rib, called a baster-plate, which was moved forward intermittently by a toothed-wheel. Whenever the end of the thin steel rib was reached, the machine was stopped, and the baster-plate returned to its original position, the cloth being then again attached. This repeated interruption of the machine in its working, marked from the very outset the one unsatisfactory part of its construction. What was obviously desirable was some arrangement by which the cloth could be so moved along as in no way to interfere with or interrupt the operations of the needle. In other words, the manifest need of the machine was that it should have no longer an intermittent but a regular and continuous feed.

As a step in the right direction towards the attainment of this object, the needle was made to vibrate vertically while the fabric, on its part, was made to move along or feed it upon a horizontal plate, a slot in which was caught and thrust forward by the upper edge of a notched wheel rotating underneath. This wheel, besides, was so timed that an intermittent motion was imparted to the horizontal feeding plate, exactly alternating with the passage of the needle through the cloth.

Improvements of this kind, suggested by Isaac Singer and other innovators, were clearly of course, to the good. But there can be little doubt that it was the introduction of what is now known as Allen Wilson's four-motion-feed, that, in this particular, brought the sewing machine to its present state of proximate perfection. This same four-motion-feed may be readily enough explained. It is begun by the moving forward of a toothed or serrated bar in a narrow elongated perforation or slot in the horizontal plate upon which the cloth or other material is fed—in the moving forward of this bar, that is to say, in the direction successively of the four sides of a parallelogram. As the first motion, the saw-like protuberances of the rough-edged bar carry the woven fabric forward while moving horizontally above the surface of the

Fig. 63.—Allen B. Wilson.

plate. As the second motion, the bar vertically drops. As the third, it passes back horizontally underneath. As the fourth, it rises to resume its original position, when it brings its teeth once more through the slot and above the surface, and in this way intermittently carries the material again steadily onwards. In obedience to the operation of such devices as cams or eccentrics upon a wheel, the motion which carries the cloth forward is so timed to a nicety that it occurs precisely when the needle is lifted away from the material, so that neither of them can interfere with the other's passage—the cloth moving with perfect freedom horizontally one instant, while the next the needle, just as freely descends perpendicularly—the two movements proceeding thus in rapid alternation. To put it in other words—When the needle has descended to its lowest point, it rises just enough to allow the loop to open out and, having paused there for the fractional part of a second until the shuttle has shot clean through the loop, it then, but not until then, reascends.

Bachelder's design for the attainment of the same object, one which was, everything considered, perhaps the first continuous feed ever applied to the Sewing Machine, employed for exactly the like purpose an endless band or cylinder which carried the cloth to and then beyond the needle—obviously a marked improvement upon the original baster-plate in Howe's machine, which, as already explained, involved the interruption of the machine's working every now and then until the baster-plate had been moved back for the commencement of a new length of sewing.

Whatever the names may be of the Sewing Machines now in general use, they are almost all of them as a rule constructed for the production—and nearly always in precisely the same way—of the famous Lock Stitch. This most desirable of all stitches, because the securest and strongest of them all, is contrived by the passing of loops of thread first of all through the material with an eye-pointed needle, and in the next place by the passing upon the other side of the cloth, through those loops, of another thread carried upon the spindled spool of a flying shuttle. Above and below the cloth, in fact, there are moving, in perpetual alternation, two perfectly distinct powers—the one above acting perpendicularly, the one below horizontally.

Sliding up and down in grooves, the former of these, meaning the vertical needle-bar carrying at its lower extremity the curved eye-pointed needle, is actuated in the Sewing Machine by the very same motor that impels the shuttle-bar which, underneath the cloth-plate, carries the shuttle through the loops momentarily left below for its reception, and which loops, in fact, open to receive it when the needle begins to retract—the two bars being so adjusted to their respective movements, horizontal and perpendicular, that their times of motion exactly correspond to each other. Thus, the shuttle—passing backwards with its bobbin while the loop, just before thrust down from above, is being drawn up again into the woven material—carries its thread through in one direction only, while unwinding just as much at each flight as tallies with the curved length necessary to the formation of a single stitch. As a preventive against the shuttle unwinding more than this, its thread is daintily retained from running out by a device known as a tension. While with kindred precaution the thread delivered from above by the eye-pointed needle is similarly restrained. Consequent upon this latter arrangement the momentary loop is retracted whenever the needle is drawn up again, the amount of its retraction being dependent entirely upon the tension, or, in other words, upon the strength of the grip with which the thread is retained. Stitches so formed have this immense advantage, that they cannot be unravelled. They fasten the goods together, in fact, with a firm and tight seam that could not possibly be produced by the earlier arrangements.

In every Lock-Stitch Sewing Machine now in use—all of which without exception it should be remembered are based upon Elias Howe's invention—there will be found grouped together into a harmonious whole three perfectly distinct kinds of apparatus. Included in the first of these three divisions are the mechanisms for making stitches and interlocking threads, for producing tension upon the thread whether supplied by the eye-pointed needle or by the spool in the flying shuttle, and beyond this for drawing up and duly securing each stitch in turn individually. What help to constitute the second division are the two surfaces between which the material in course of being sewed is so smoothly and tightly detained that they support it against the thrust and withdrawal of the needle in such a position as admits quite readily of the stitches being dragged home and securely fastened. As for the third and last of these three all-important linked divisions in a Lock-Stitch Sewing Machine, it is the apparatus by means of which an automatic, interacting feed is ensured to the material by its being caused to advance with a regular and uninterrupted movement between the holding surfaces during the hardly measurable interval which elapses between the successive punctures made in the cloth by the needle.

So complete and radical was the transformation which resulted from the day when Elias Howe made evident the fact that the work of human hands could thenceforth be done with the utmost facility, swiftness and precision by machinery, that more than twenty-eight years before the date at which I am writing these words, the *Mechanic's Magazine*, on the 23rd November, 1860, declared it to have been satisfactorily proved by then recently published statistics that £58,000,000 per annum represented, even then, the value of the sewing actually being done at that time by machines in the United States alone! Supposing money, it added, to be worth only two per cent. per annum—surely a most moderate supposition—the Sewing Machine represented, therefore, upon that unexaggerated estimate, a capital of £2,900,000,000! Bearing all this in mind it can hardly be considered that Howe—who had perfected in 1862 his original invention of 1845—in any way put a mere fancy value upon his patent when, upon his petitioning Congress on the 15th July, 1867, to grant him a second extension of time, he insisted that his contrivance was worth at a reasonable computation at the least $150,000,000.

It is curious to remember, now, in regard to the discovery by him of the first really Automatic Sewing Machine, that another and not the least remarkable illustration was afforded at that time of the fact, which in the history of science has been so often demonstrated, that whenever a truth is ripe for discovery it is hit upon all but simultaneously by two perfectly distinct and independent investigators. Thus, in the present instance, but a very few months after Elias Howe had completed his first Automatic Sewing Machine, a stripling of no more than nineteen years of age, named John Fisher of Nottingham, constructed upon precisely the same principles, a wonderful lace-making machine of such marvellous elaboration that it consisted of upwards of nineteen thousand separate pieces of mechanism—both Howe and Fisher employing the same means for carrying and interlocking the thread, to wit the eye-pointed needle and the flying-shuttle! Very clearly indeed, for the new World Wonder, the Hour had come, and—as usual with the repercussion of a double knock announcing his advent—the Man!

Thenceforth, more and more distinctly as the years ran on, the needle-woman's occupation was virtually abolished. Thenceforth, in dwindling progression, the craft of the tailor and the sempstress glided at a perpetually accelerated pace "down the ringing grooves of change" to the obsolete! Automatic machinery from that time forward began to do so rapidly and so unerringly the work of human hands, that the veriest village crone had ample reason every day to exclaim with Lady Dufferin's wondering goodwife, that she felt—

> Quite superannuated and laid upon the shelf
> To see a worsted stocking get up and knit itself!

Not merely sewing and stitching were done from that time forward as with the rapid palpitation of a piston in a steam engine, by the wonder-working sewing machines of Howe, Singer, Weed, Florence, Wilson, Secor, Wanzer, Rennington, and all the rest of them, but just as skilfully also hemming, felling, ruffling, cording, basting, braiding, binding, quilting, marking, embroidering—in fact every conceivable device that a dreamer might have imagined to himself to have been worked out with a fairy needle and thread at the bidding of a necromancer.

Miracles of ingenuity, it is the merest matter of fact to say, marked the progress of contrivance in the rapid advance and improvement of the sewing machine from the time when the American machinist brought out of his garret in Cambridgeport proof positive that needlework could be done by machinery.

A miniature Cutting and Sewing Machine, for example, was actually constructed at one time as an attachment to a pair of scissors—the thread-spool of it being at the top, the cloth passing between the nipping plates, the eye-pointed needle carrying the thread through the fabric, on the other side of which it was left in a loop, which loop at the needle's next descent was transfixed by another loop its immediate successor, and so on—a symmetrical chain-stitch being in this manner wrought in the cloth at the very moment of its being cut into whatever shape was required.

Sneath's machine, again, similarly made chain-stitch ornaments upon bobbinet during the actual process of that bobbinet being manufactured.

Another Sewing Machine, which was designed for the production of a chain-stitch, was most ingeniously contrived by its inventor out of a single slip or strip of sheet-metal, pointed at one end, marked throughout its length with six divisions for bending, having seven circular, one square, and two oblong perforations, and a lateral extension shaped like a boot-jack almost at its middle.

Garland's spiral needle is the title of another most ingenious contrivance patented as recently as in 1871, for the sewing of bags. Shaped like a corkscrew, its thread lies spirally along its whole length in a continuous groove, being secured by a delicate spring at its extremity. Through its agency the edges of the bag are rapidly yet circuitously sewed together upon being laid in its track, the needle as it revolves passing through both sides once in every revolution.

Curiously enough the fastening of the edges of a material together was the earliest purpose to which a Sewing Machine was ever applied, the simple object then held in view being, in Bean's patent of the 4th March, 1843, to sew calico together prior to its being bleached or dyed or printed. The edges of two portions of the calico having to this end been placed side by side, were in that instance first of all crimped or corrugated by being passed between fluted rollers, and were then forced on to a common sewing needle which, for the purpose of receiving it, was held stationary in a horizontal position. A momentary placing in juxtaposition thus of that simple device and of Garland's spiral arrangement already mentioned may serve as well as anything else to illustrate the extraordinary advance made in the development of Sewing Machine contrivances generally during the eight-and-twenty years which had intervened. Every variety of stitch within that interval had been rendered practicable by means of machinery: not merely the ordinary running stitch used in basting, but in addition to that the back stitch, the fast stitch, and the chain stitch, together with those

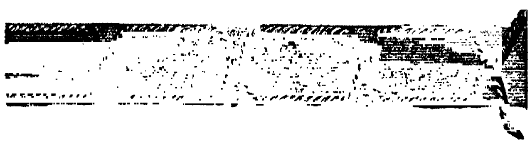

Fig. 64. The Lock Stitch.

three distinct kinds of loop chain stitch, known as the coiled, the knitted, and the knotted, but above and beyond them all the incomparable lock stitch.

Occasional peculiarities have been observable even among the Lock Stitch Sewing Machines, peculiarities in some few instances so pronounced as to have imparted to the machine to which they have been adapted a distinct individuality. A case in point was that of the Florence Sewing Machine, which instead of having its needle carried by a needle-bar and moving vertically in guides, had its curved needle attached to the end of a vibrating arm. Another was that of the Lock-Stitch Sewing Machine invented by James House and manufactured by Wheeler and Wilson, which, in lieu of locking the loop thrust through the cloth by the eye-pointed needle with the aid of a shuttle flying along a shuttle-race, accomplished the same end by means of a rotating hook, in that manner completing a stitch at every revolution, besides

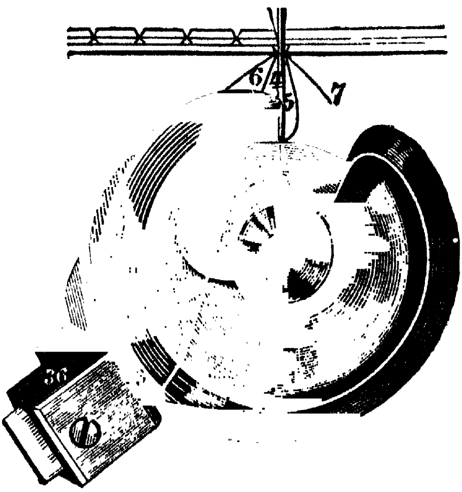

Fig 65 —The Rotating Ho

drawing the thread well home with the help of a separate arm known technically as an independent take-up. This peculiar take-up arrangement was nothing else, by the way, than a device by means of which the upper thread was so drawn upon as to recover or take up its slack while the needle was in the act of rising or was actually resting at its highest point, the stitch in this way being directly and effectually tightened.

Whenever, in the work done by a sewing machine the thread is found, on being accidentally fractured, to unravel rapidly with a ripping sound from one end of the seam to the other, you may be absolutely certain of this, that it is the product of a chain-stitch and not of a lock-stitch Sewing Machine. Bear in mind for a moment, in proof of this, what it is that is meant by the chain-stitch, or the tambor stitch as it is otherwise designated. It is simply the bight of a thread, or in other words a loop, thrust through a previous loop, which in its turn is enchained by its successor, and so on indefinitely. Whether made by a crochet needle and a looping hook, or by an eye-pointed needle and a detaining hook, it can never be counted upon as a stitch that is in any way durable. Let one end of it at any time be snapped and away it all goes by mere unravelment! Consequent upon this its great inherent defect, the chain-stitch has long ago been superseded by other stitches, but principally of course by the peerless lock-stitch.

Nevertheless, by reason of its cheapness and general excellence, one kind at least of Chain-Stitch Sewing Machine, that of Willcox and Gibbs, still retains a high degree of popularity, principally no doubt because in it the natural tendency of the stitch to unravel has been to some extent interfered with and partially conquered, by each loop in turn being twisted in the very act of being made, thanks to the clever little mechanical arrangement contrived by Gibbs of Mill-point in Virginia. Compact and portable though the Sewing Machine is, by whomsoever manufactured, the diversity of its component parts is something remarkable. A mere enumeration of some of the salient

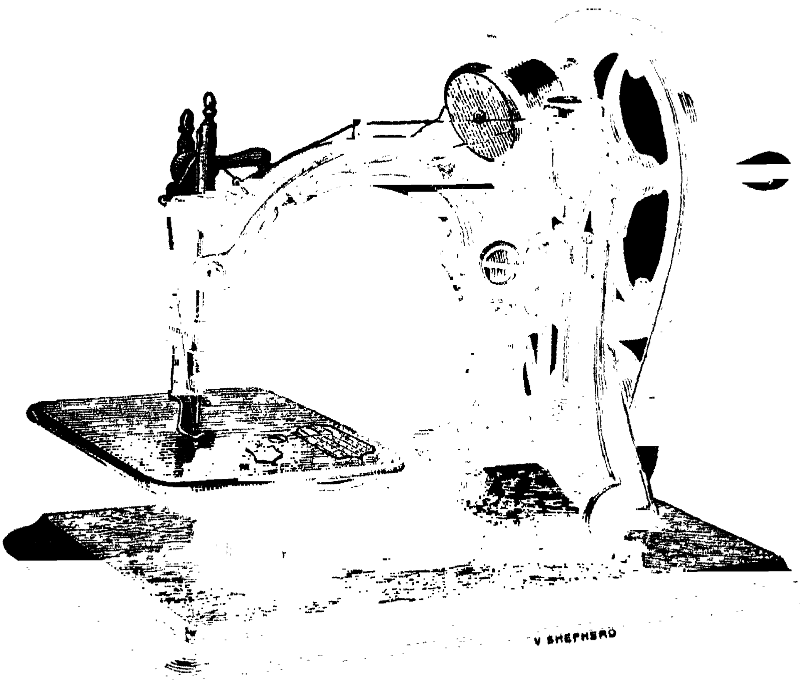

Fig. 66.—The Willcox and Gibbs Sewing Machine.

portions of this most delicate and yet durable piece of mechanism will indicate this perhaps as readily as anything. Conspicuous among them, besides the needle and the shuttle, are the spools and bobbins, the take-up and tension devices, the clothplate and pressure-foot, the needle-bar and the shuttle-race, the tables on which they stand and the cases or cabinets in which they are enclosed; to say nothing of such essential accessories as the needle-sharpeners, the needle-setters, the needle-threaders, and the bobbin-winders, or such attachments, again, as those for binding, braiding, cording, piping, ruffling, gathering, welting, quilting, hemming, and embroidering.

Now that the genius of Elias Howe and his successors has called the perfected Sewing Machine into existence, it is literally as if, in the busiest woikshops all over the world, and in countless quiet homes, there were realised at pleasure about the daintiest of all the fairy imaginings of the Brothers Grimm, that of the Elves and the Shoemaker. Nothing more nowadays need be done by anyone, in fact, with a view to the wielding of the needle, than was done by the hero of that elfin legend, of whom it is related that he merely cut out the goods piecemeal which he desired at any time to have put together. Having done this, as we read—There, shortly afterwards, to his great wonder, stood the article of raiment in its completed form—all ready-made upon the table. The good man knew not what to say or think of this strange event, it is added. He looked at the workmanship; there was not one false stitch in the whole job; and all was so neat and true that it was a complete masterpiece.

V.—THE SPECTROSCOPE.

"As through a glass darkly."—St. Paul.

"Measuring infinitude with a two-foot rule," is a phrase which has long ago passed into a proverb as illustrative of the highest flight of human folly. And yet modern science, with the aid of a triangular bit of glass but an inch or two in length, has contrived, with the utmost possible ease and precision, to sound in all directions the illimitable abysses of the universe.

A little more than two hundred years ago — as already explained here in the preamble of the account given of the discovery of the Photograph—Sir Isaac Newton, in 1675, first demonstrated the fact, until then wholly unconjectured, that the sunbeam, though to all appearance nothing more nor less than pure white light, in reality contains within it every imaginable variety of colour. This astounding truth, it will be remembered, was then made clear by Newton, not alone to the understanding but to the eyesight of the assembled members of the Royal Society, upon his admitting a single beam of light through a small round hole into a darkened chamber, and thereupon decomposing it by allowing it to pass through a prism, the refracting power of which opened out from it like a fan, the gorgeous constituent rays until that moment exquisitely combined. As the illustrious philosopher remarked twelve years afterwards in his immortal treatise upon "Optics," which was published in 1704, the magnificent variety of colours thus revealed depends entirely upon the composition of the light from which

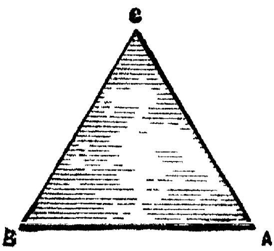

Fig. 67.—Sectional View of Glass Prism.

they are unfolded. Entering the prism as an arrowy beam of white light, the constituent rays, according to their refrangibility, emerge from it in a resplendent band of dazzling radiance, known now familiarly for two centuries and more as the Solar Spectrum. In it, the sequence of the prismatic colours, ranges invariably from the least bent rays to those which are upon a tenderly graduated scale more and more widely deflected; that is, from Red on to Orange, to Yellow, Green, Blue, Indigo, and Violet; with every intermediate tint where the one hue melts almost imperceptibly into the other, its immediate neighbour. Through the cut-glass drops of a lustre on a mantlepiece, or through those of a pendant chandelier in a drawing-room, these prismatic dyes are, indoors, by every burst of sunshine, cast in profusion upon surrounding objects, upon carpet, wall-paper, ceiling and furniture. Reflected and re-

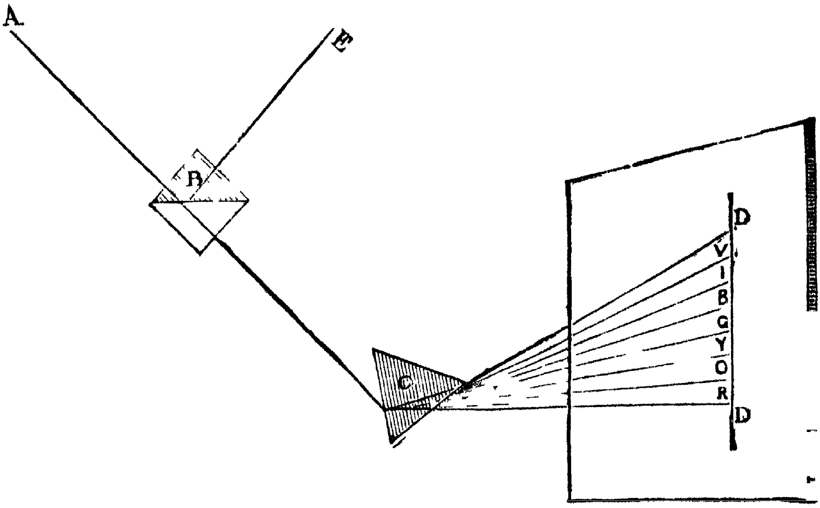

Fig 68 —Decomposition of Light through Prism

fracted, again, in every particle of falling moisture in a shower, they are visible to the whole world, in their most splendid aspect, out-of-doors, in the triumphal arch of the rainbow.

When the Solar Spectrum had been familiar, thus, for a hundred years and upwards to the philosophers of both hemispheres, it suddenly occurred to Dr. William Wollaston in 1802 that he would subject it to the test of an entirely new experiment. Whereas Newton had admitted the sunbeam to the darkened room through a small round hole, Wollaston bethought himself that he would give it access to the chamber through a very narrow slit in the shutter. Examining it thus, after its deflection through the prism, what was his astonishment

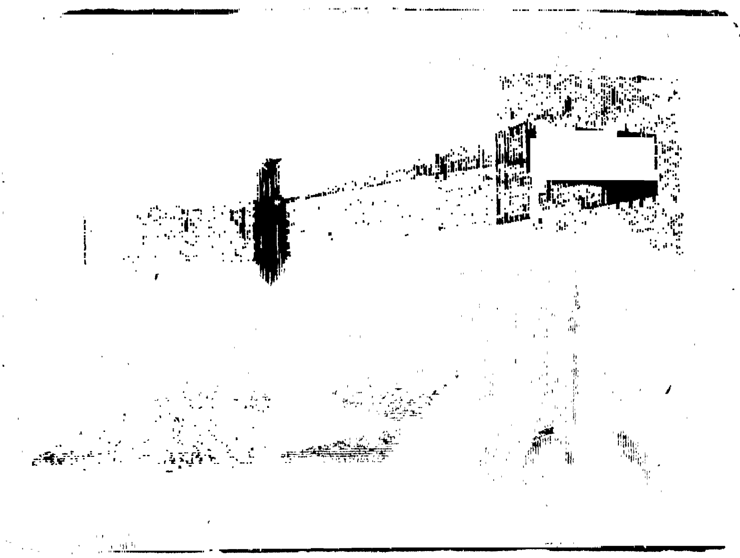

Fig 69 —Wollaston's Experiment, No 1

to observe that the whole field of the solar spectrum —through all its sequence of colours, Red, Orange, Yellow, Green, Blue, Indigo, Violet,—was scored down (as in a chromatic scale) at irregular intervals by certain mysterious dark lines of more or less distinctness. Out of Wollaston's discovery of those until then undreamt-of dark lines in the Solar Spectrum, there eventually sprang into existence about a quarter of a century afterwards, one of the most marvellous applications of natural philosophy ever conceived by the ingenuity of man. Unsuspected by him, Wollaston, through his revelation of the dark lines in the spectrum, was throwing out the first hint, in fact, for the building up, later on, of the now world-famous science of Spectrum Analysis.

Wollaston, who, four years after this, in 1806, became Secretary of the Royal Society, was chiefly known in

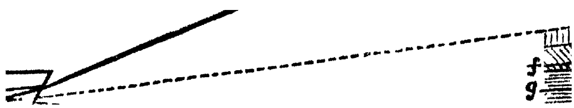

Fig 70 —Wollaston's Experiment, No. 2.

his time as the discoverer of a process for disengaging platinum from its native ore, and rendering it malleable. His success in so doing secured him, in fact, gold medals, wealth, and a reputation. There can be no question, however, that his main title to remembrance is recognisable nowadays, not in what his contemporaries doubtless regarded as his paramount achievement, but far rather than that in the apparently trivial circumstance by comparison, that he was the one who first revealed those curious dark vertical lines in the Solar Spectrum. In his mode of conducting his experiments, the prism was held near the eye—sunlight being thus visibly deflected into a gorgeous spectrum, ribbed from one end of it to the other with black lines at unequal distances from each other ; some close together, others far apart; some delicate as a spider's thread, others thick and strongly pronounced. Wollaston, besides this, was the one who first subjected the light of the electric spark, and of different coloured artificial flames to a similar examination, bright instead of dark lines being revealed in the spectra thus produced.

Another investigator of these phenomena, himself at the outset of his career entirely ignorant of Wollaston's earlier experiments, arrived some little time afterwards at precisely the same conclusions. This was the now famous Bavarian *savant*, Joseph Fraunhofer, with whose name the dark lines in the Solar Spectrum have since then in some sort come to be identified. Under his scrutiny in truth they were subjected to what might almost be called an exhaustive investigation. He it was who mapped them out so completely in 1814 that thenceforth they have been known all over the world as Fraunhofer's lines. All the salient dark lines in the Solar Spectrum—each duly lettered and numbered, to an aggregate of 354 altogether—are there clearly defined in Fraunhofer's publication. Nearly six hundred lines (to be precise just 576) were counted up by him in the end—while other minuter scrutinizers of the Solar Spectrum have contrived since then to make out a grand total of absolutely two thousand. But there can be little doubt that in Fraunhofer's original draft of the solar spectrum band, marked off irregularly through Red, Orange, Yellow, Green, Blue, Indigo, and Violet, the all-important black lines of demarcation are laid down with scrupulous accuracy. What is chiefly remarkable about them is this, that they are invariably the same—

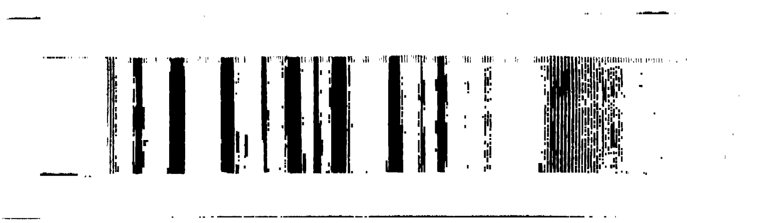

Fig. 71. —Fraunhofer's Lines.

that is, at least when the Solar Spectrum, pure and simple, is submitted to examination. Let it be viewed, for example, when the sun is at the meridian; the dark lines in it reveal then no variation whatever, either in their number or in the manner of their arrangement.

It is only when the sun is rising from the eastern, or sinking towards the western horizon, and when its beams consequently have to penetrate horizontally through a greater thickness of the earth's atmosphere that supplementary lines, so to speak, traceable every-one of them obviously to the influence of the latter (that is, of the earth's atmosphere), are here and there in the variegated ribbon of the spectrum—from Red to Violet—interpolated. Another fact in regard to the Solar Spectrum is equally remarkable—namely that the dark lines in it are identically the same in their relative position in the different colours, whether it happens to be derived directly from the sun itself, or indirectly by reflection from the moon, or from one of the earth's sister planets. Entirely different, however, are the spectra produced by the prism from the light derived from the fixed stars—a circumstance in itself demonstrative of the fact that the dark lines in the spectrum of the sun and those in the spectrum of any one of the fixed stars, being relatively or entirely different, cannot obviously be attributed to the influence of the earth's atmosphere. More than this, a series of magnificent experiments has made clear the fact that a spectrum marked vertically with bright instead of dark lines of a distinctive character, is produceable through the prism from light derived from the ignited vapour of each in turn of the earthy elements.

As for the meaning of the dark lines in the solar spectrum, Dr. Ritchie has the merit of having been the first to demonstrate that they are non-luminous spaces directly caused by absorption, as was made clear through the fact of his having by artificial means contrived visibly to increase their number. Of so reliably permanent a character are they in the Solar Spectrum along the whole sequence of its prismatically coloured bands, that their minutest subdivisions can be referred to, by letter or by number, with the most absolute certainty, precisely as they were first laid down in 1814 by Joseph Fraunhofer. Nay, Sir David Brewster, who carried his researches yet further and wider afield insisted that the luminous band of the Solar Spectrum is divided into more than 2000 visible and easily recognizable portions, separated from each other by lines more or less clearly distinguishable. He it was who, in 1822, while carrying out his experiments in regard to the spectra of flames of different colours, suggested the plan of using to this end spirit lamps with salted wicks, through the employment of which monochromatic light might be readily obtained.

Inspired by a kindred notion Sir John Herschel almost simultaneously examined, with the aid of the prism, red light produced by chloride of strontium, three different kinds of green light produced respectively by chloride of copper, by nitrate of copper, and by boracic acid, as well as a rich violet light produced by chloride of potassium. Whether in salts or in chlorides, these substances, it was soon found, were readily applied in the form of powder to the wicks of spirit lamps with the most brilliant results in the way of spectral experiments. Long before the time of Sir David Brewster and Sir John Herschel, a similar test had made plain the fact that compounds of sodium revealed the brightest yellow line in the spectrum. It was now found, not only in regard to that, but in regard to every-one in turn of the terrestrial elements, that extremely minute quantities, infinitesimal particles even, might with the aid of the prism be readily detected.

In Fox Talbot, however, far rather than in any of those whose names have here been enumerated, the original suggester of the wonderful science of Spectrum Analysis ought in justice to be recognised and announced. He it was who, in a remarkable paper, published in 1826, suggested the principle that whenever the prism reveals a homogeneous ray of a specific colour to exist in any flame, that homogeneous ray should be regarded as indicating the presence there of some definite chemical compound. Further than this he wrote in so many words eight years afterwards, "I hesitate not to say"—this was in his paper of 1834—"that optical analysis can distinguish the minutest portions of these substances from each other with as much certainty as any other known method, if not with more." In justification of which opinion, sodium, which is as widely diffused as almost any element that could be named, betrays its presence instantaneously in the spectrum, the smallest atom of it when ignited producing the intensest yellow line.

Whereas Wollaston, in 1802, as already shown, placed the prism at his eye when making his initial experiments, Fraunhofer in 1814, after removing it 24 feet from the slit, examined the spectrum under those altered circumstances, not with the naked eye, but with the aid of a telescope. By this means, of course the ribbon of parti-coloured light revealed, was greatly magnified, the dark perpendicular lines disclosed appearing at the same time much more numerous.

So subtle and so searching was the test thus placed at the command of experimentalists, that Fox Talbot in 1834, was enabled with the utmost ease and certainty to distinguish the difference between the otherwise apparently identical red flames of lithia and strontia, while Professor William Allen Miller was empowered, in 1845, to carry into effect with the happiest results a series of masterly experiments in regard to the spectra of the alkaline earth metals. He and Professor Wheatstone, by the way, were the first to suggest—in consequence of the rigidly exact and unvarying position and characters of the bright lines revealed in the spectra of differently coloured flames—the adoption of prismatic or spectral analysis as an infallible means of revealing the presence of any substance, it hardly matters in how microscopically minute particles. And in proof of the reasonableness of the proposition, Dr. Bence Jones, acting years afterwards upon the hint thus thrown out, detected in a living body certain metallic atoms which had been introduced into it only a few minutes previously.

Later and greater developers of the science of Spectrum Analysis were to come, however, than any, even the most illustrious of those whose names have here already been particularized. To two German Professors more especially belongs the glory of having by their profound researches imparted to it as a science its loftiest and sublimest expansion. These men—Professor Bunsen, and Professor Kirchhoff—may be said, without any extravagance of language in so speaking, first to have rooted it as a science upon enduring foundations, and afterwards, while directing their gaze upwards, to have lifted it into the empyrean. It would be in no way hyperbolical to insist in their regard that, pre-eminently and before all others, those two are the originators and founders of Spectrum Analysis as the world now knows it.

Gradually, bit by bit, in obedience to the requirements of a long succession of experimentalists, there had been growing up meanwhile in the hands of the mathematical instrument makers, a wonderful piece of mechanism designed for the better carrying out of these most delicate researches. This is the wand, in fact, with which that latest Prospero, the Spectral Analyst, conjures. Armed with it, he has been enabled to detect in otherwise invisible and inappreciable atoms, one, two, three, four new metals of which man had never previously suspected the existence. It has empowered him to discover with absolute certainty what are some among the constituent elements of the sun, of the planets, of the comets, of the fixed stars, of the

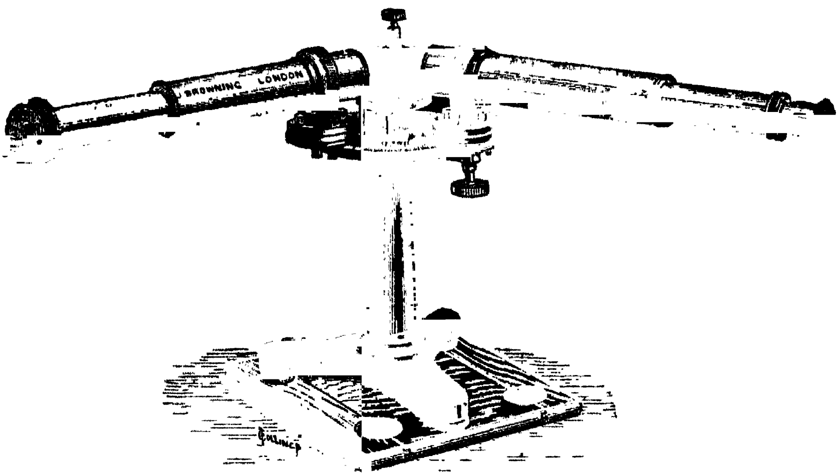

Fig. 72.—The Spectroscope.

very nebulæ Everybody is familiar with the name at least of this wonderful instrument—the Spectroscope.

In its simplest form, it is a combination of a prism with two tubes (one of them a telescope) making an angle between them. These, otherwise securely fixed upon a stand or table, are at the same time capable of adjustment in themselves and relatively to one another, their movements being regulated to the utmost nicety by such means as delicately adjustable screws, or racks and pinions.

Whenever the Spectroscope is in use, a veil or curtain of black cloth is thrown over the prism and the ends of the tubes, so that all extraneous light is effectually excluded. Fifteen inches long is the tube by which the light is admitted to the prism through an exceedingly narrow slit, one fortieth of an inch across, this slit being

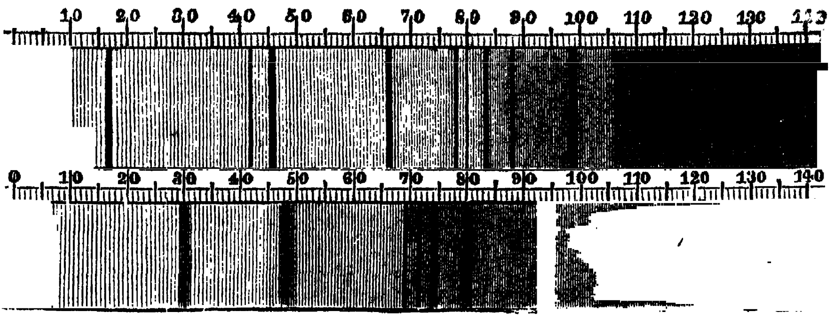

Fig. 73.—Spectra with Graduated Scales.

formed by bringing two knife edges close together. Eighteen inches long is the telescope, the eye-piece of which is armed with a micrometer for observing accurately the dark lines or bands in the spectrum. A delicate Vernier in fact is attached to the eye-piece, meaning one of those short graduated scales capable of sliding along a lengthier one, and thus readily indicating the fractions of divisions, so that the position of any line in the spectrum, dark or light, may be most accurately determined, relatively, that is, to the principal lines of Fraunhofer. Placed intermediately between the object-glass of the tube and that of the telescope, the prism should present one of its edges to each, that in front of the object-glass of the tube being directly parallel with the slit. Such, in brief, used to be

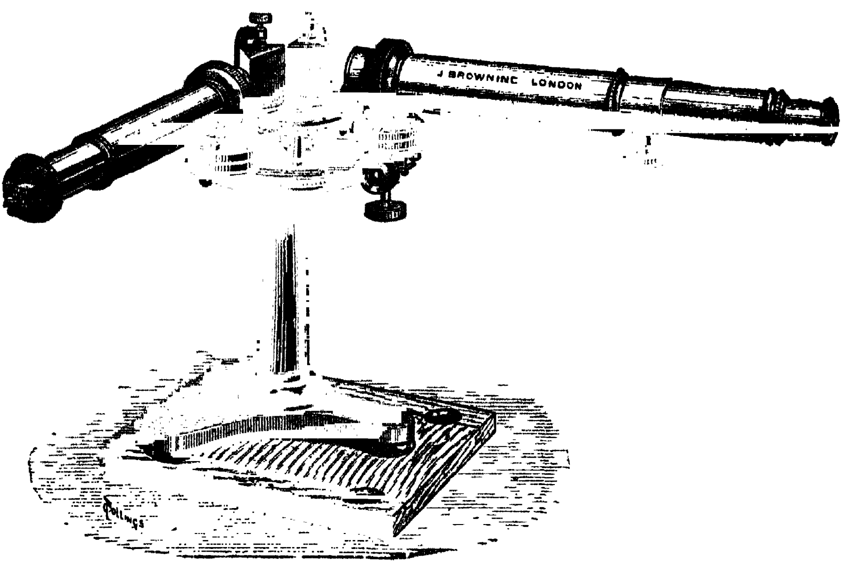

Fig 74 —Spectroscope with Two Prisms.

the ordinary construction at first of the wonder-working Spectroscope. It was found convenient, however, for particular purposes, that the two telescopes—the telescope proper, that is, and the one having the knife-edged slit instead of the ordinary eye-piece—should have a common axis. Steinheil, the eminent maker of these instruments at Munich, constructed one of this character, in which the direction of the ray through a combination of three prisms was maintained by means of external reflections. Latterly, however, it has become usual to employ several prisms, not merely two or three, but sometimes as many as fifteen or even twenty in the fabrication of the Spectroscope. Nine, for example, are combined in the marvellous Spectroscope at Kew Observatory, which reveals the dark lines of the Solar Spectrum with a vividness that has never been exceeded, if indeed it has ever been equalled. By passing the light thus through a succession of prisms—as in this masterpiece from the workshop of Mr. John Browning of the Strand—the rays are opened or spread out more and more widely at each passage, so that there is secured in the end a greatly increased dispersion. Through this extreme lengthening out of the Solar Spectrum the dark lines are kept so thoroughly well apart that a scale is formed, the exquisite delicacy and unalterable character of which admit in no way of being surpassed.

Aided by instruments of lesser power than this, though still of extraordinary excellence and masterly construction, Professor Bunsen, in 1860, startled the scientific world by bringing to light the existence of two new metals through the agency of the Spectroscope. Cæsium, meaning literally bluish grey, was one of these; Rubidium, so called from *rubidus*, the darkest ruby red, being the other. Infinitesimal particles of the latter were thus detected—they would have been utterly

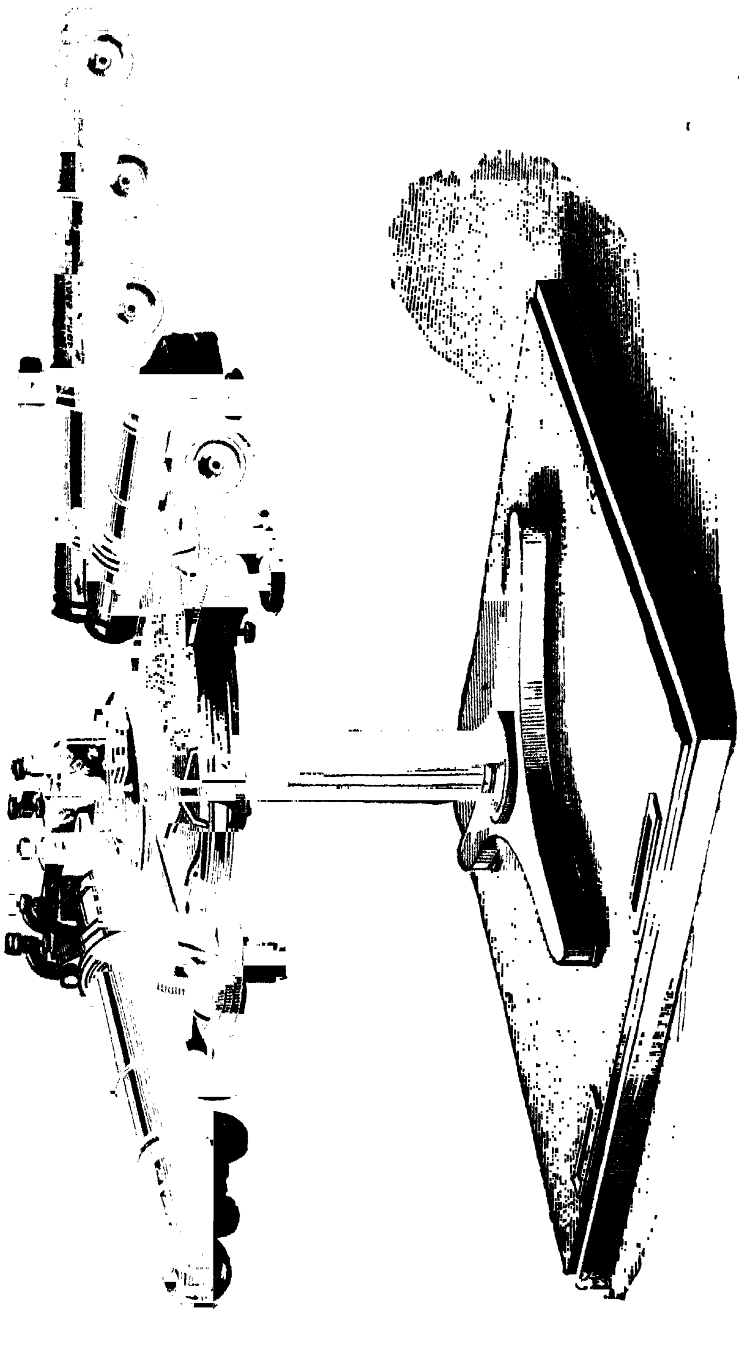

Fig 75 —Spectroscope with several Prisms.

undistinguishable by any less subtle means—in certain mineral waters of Germany, at Durckheim. Thallium, a third metal, was shortly afterwards discovered by Mr. William Crookes; and Iridium, a fourth, by Professor Richter, in the midst of similar researches conducted by them with the help of the Spectroscope. A worthy compeer and colleague of Professor Bunsen, however, appeared in 1860, in the person of Professor Gustav Kirchhoff, who soon made good his claim to be regarded as the arch-exponent of the new-born science of Spectrum Analysis. His daring investigations with the aid of the Spectroscope, were at once rendered famous by his luminous exposition of the astounding facts which were thus in rapid succession arrived at.

Professor Nichol more than twenty years previously in his "Architecture of the Heavens," had with a superb hyperbole spoken of modern astronomers as "carrying among the spaces of the fixed stars the precise tape of the surveyor, and dividing their intervals with milestones." Seeing that the telescope had now called to its aid the marvellous agency of Spectrum Analysis, something far more wonderful was achieved than the mere measuring out of inter-stellar distances.

Armed with the Spectroscope, philosophical enquirers thenceforth found themselves enabled to throw a flood of entirely new light upon the constitution of the universe. Although their researches in regard to the

Sun, for example, could be carried on only across an abyss of ninety-one millions of miles, they were yet able, thanks to the potent instrument newly placed at their command, to realise the astonishing fact that in that

Fig. 76.—Gustav Kirchhoff.

remote orb there are for certain ten metals common to it and to this earth of our own, namely, iron, sodium potassium, chromium, magnesium, nickel, calcium, barium, copper and zinc. Kirchhoff, by one of his most magnificent discoveries, made plain the fact that hydrogen also is present in the solar atmosphere.

Applying the test of Spectrum Analysis to the Comets and even to the Nebulæ, it was distinctly proved that these were nothing more substantial than enormous masses of glowing hydrogen and nitrogen gas, careering through space with frightful velocity, and in a state of intense incandescence. While, upon analysing the star-light, these two startling truths were very clearly demonstrated, first that one and all of the Stars are con-

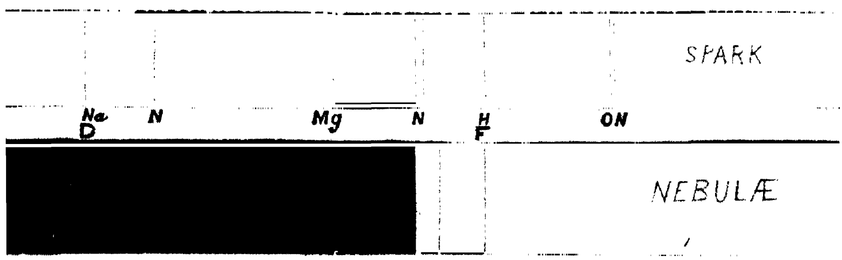

Fig. 77.—Spectrum of Nebulæ and of Electric Spark.

structed very much after the same fashion as the dazzling centre of our own system; and yet, in the next place, so far as all research in this matter has yet gone, that a marked difference is observable in the spectrum of each Star that up to this time has been examined. For, as Saint Paul says (1 Cor xv. 41), "There is one glory of the sun, and another glory of the moon, and another glory of the stars; for star differeth from star in glory." How it is that the physical constitution of the heavenly bodies can thus be deduced with an absolute certainty from the revelations of Spectrum Analysis, may now in a very few words be readily explained.

It is a simple matter of fact to say that light is producible from everything, provided only whatever is expected to give it forth be sufficiently heated. Sun, Stars, Comets, Nebulæ, all of them radiate light merely because they are in a state of absolute ignition. As Faraday first of all explained, besides, the all-but blinding radiance of the Electric Spark is attributable to the combustion of minute particles of the terminals,

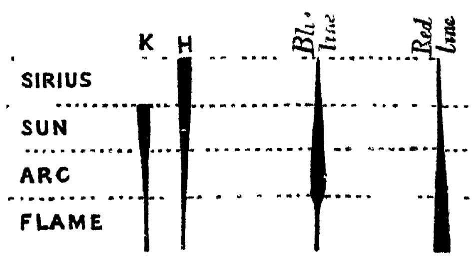

Fig. 78.—Differences of Spectra.

as well as of the air and other matter through which the electric current passes from one of these terminals to the other. Artificial light of every kind, whether produced by oil, gas, wax, tallow, or what not, emanates from the white hot particles of carbon in whatever is there in a state of combustion. Knowing perfectly well from the first that light of any kind, however produced, admits of being prismatically analysed, the optical philosophers, so soon as they had obtained a mastery of the Spectroscope, began to subject one thing after another to this most searching kind of disintegration. Every terrestrial element, it was speedily found, gave forth, when its vapour was ignited, rays so peculiar to itself that it was thenceforth easily identified. One after another, all the spectra obtained from the light emitted from incandescent mineral bodies, it was rapidly perceived, differed altogether from the Solar Spectrum—bright lines and not dark lines, beside this, becoming instantaneously apparent.

That lights of the most vivid and varied colour can be artificially produced with the greatest ease, has long been rendered patent to the whole world by some of the most familiar devices of the stage manager and the pyrotechnist. But for this, firework displays would lose half their attraction, and some of the perfecting charms of theatrical illusion would be altogether lost Strontium, for instance, gives forth the red and lurid light which is so often effectively introduced in the transformation scene of a pantomime. Barytes, again, may be recognised by many as the source of that pale, livid, greenish light which is diffused over ghostly apparitions in a melodrama. Soda or common salt produces a radiant yellow, copper burning with the richest green, iron with an orange brown, lithium with a gorgeous crimson. Any artificial flame thus tinted immediately a ray from it has passed successively through the chink and prism of a spectroscope, reveals unmistakeable evidence of the existence in the flame of the element from which it has emanated. A well-defined spectral image in fact is obtained about the identity of which there cannot be any doubt whatever. As illustrative of this, two or three of the metallic spectra may be here particularised. That of strontium shows six red lines, one orange, and one blue. That of lithium discloses two sharply marked lines, one of them bright red, the other yellow. Calcium makes itself

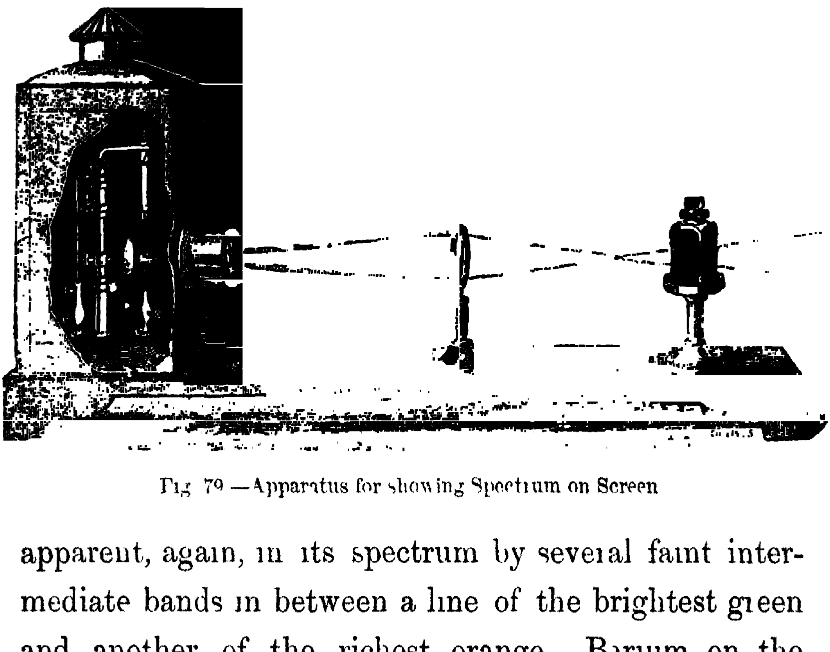

Fig. 79.—Apparatus for showing Spectrum on Screen.

apparent, again, in its spectrum by several faint intermediate bands in between a line of the brightest green and another of the richest orange. Barium, on the other hand, betrays itself by an array of bright green lines, several yellow lines of varying intensity, one of red, and another of orange. What is especially remarkable, in regard to the luminous coloured demarcations noticeable in the spectra thus artificially evolved from the prism of the Spectroscope, is the fact that they so often tally precisely with the dark lines in the Solar Spectrum. Upon a comparison of the spectra of incandescent gases with that grand standard, the fact has been again and again demonstrated, that the position of the bright lines thus artificially produced is in exact harmony with the position of the dark lines in the Solar Spectrum. It is from Kirchhoff's memorable recognition of this, that dates the first glimpse obtained by man of the physical constitution of the sun's atmosphere. Not one or two merely, but several earthly elements have revealed by this time very clearly indeed, that the bright lines on their spectra are absolutely identical with the dark spaces observable on the Solar Spectrum. Difficult of explanation though that curious identity between the bright and the dark lines might at the first glance appear to be, it turns out after all to be a problem, comparatively speaking, easy of solution.

According to the account which is now very generally admitted to be the true one as to the origin of the non-luminous spaces, or dark lines in the Solar Spectrum, the light emanating from any incandescent body in the very act of passing through an ignited vapour gets, so to express it, sifted or absorbed, the rays thus sifted out or eliminated being in point of fact exactly those which the burning vapour itself radiates. Thus, according to the dictum of the founder of Spectrum Analysis, the light emitted by the light-giving envelope or photosphere, as it is called, of the Sun, in darting forth from that great luminary, gets absorbed by the vapour of various heated substances in the solar atmosphere, and this so effectually that the only light that eventually reaches our globe is that which in escaping through the solar vapours has succeeded in avoiding the risk of that absorption.

Immediately, therefore, upon its being rendered apparent that the dark lines in the Solar Spectrum were absolutely identical with the bright lines revealed by the spectra of certain ignited terrestrial metals, the obvious deduction arrived at was that the vapours of those very metals were, as they are now known with the most perfect certainty to be, existent in the Sun's atmosphere. "In order to test in the most direct manner possible," wrote Professor Kirchhoff, in 1861, "the truth of the frequently asserted fact of the coincidence of the sodium lines with the lines D, I obtained a tolerably bright Solar Spectrum, and brought a flame coloured by sodium vapour in front of the slit. *I then saw the dark lines D change into bright ones.* The flame of a Bunsen's lamp threw the bright sodium lines upon the Solar Spectrum with unexpected brilliancy!" Not satisfied with this demonstration, Kirchhoff relates how he went on to yet another—with what startling results he himself thus strikingly recounts. "In order," he continues, "to find out the extent to which the intensity of the Solar Spectrum could be increased without impairing the distinctness of the sodium lines, I allowed the full sunlight to shine through the sodium flame upon the slit, and *to my astonishment I saw that the dark lines D appeared with an extraordinary degree of clearness.*" Having made that impressive entry, he goes on a little later in the record of his "Researches" to remark, that the phenomenon is easily explicable on the supposition that the sodium flame absorbs rays of the same degree of refrangibility as those it emits whilst it is perfectly transparent for all other rays! Further on, in support of this conjecture, he directs attention to the fact that nitrous acid and iodine vapour visibly possess in the same way that most curious property of selective absorption.

Kirchhoff, at the time when he was carrying out his immortal "Researches on the Solar Spectrum, and the Spectra of the Chemical Elements," was Professor of Physics in the University of Heidelberg. In association with Bunsen, he had but very recently before inaugurated that hitherto unthought-of department of Chemical Science, the application of spectrum observations to what is termed qualitative analysis, meaning the resolving of any compound into its constituent parts in contradistinction to so-called quantitative analysis, which signifies the determining of the proportions in which those constituent parts are combined. In the prosecution of his enquiries, he compared one after another with the Solar Spectrum the spectra of a great number of the fifty metals, demonstrating as the result of his august investigations that these same familiar earthly metals of ours are widely diffused throughout the universe.

An Englishman of kindred genius, William Huggins —a name now honoured all over Europe as that of a worthy rival of Gustav Kirchhoff—almost immediately upon the announcement of the sublime discoveries which had been made at Heidelberg, was inspired with an ambition, to follow energetically along the track already marked out with such resplendent results by his illustrious contemporary. Beginning his astronomical studies as an amateur in the midst of the murky atmosphere of London, Mr. Huggins had some little time before this withdrawn from that "province of houses" to a more congenial locality, and prior to the time when the initial truths of Spectrum Analysis may be said to have been formulated by Bunsen and his associate, and signalised by these first grand discoveries, had, under a purer sky, in the grounds adjoining his residence on Upper Tulse Hill, erected for himself a suitable observatory. There, night after night, he devoted himself at every fitting opportunity to the examination of the heavens, singling out most frequently by preference as the special objects of his research, the Double Stars, Mars, Jupiter and Saturn. While absorbed in these occupations, the news came to him of the marvels opened up to view—here upon the earth, yonder in the heavens—by the mystic lenses of the Spectroscope. The intelligence brought to him in his suburban retreat would seem, from the very outset, not only to have roused his energies but to have captivated his imagination. With the very beginning of 1862, he appears to have entered in earnest upon those profound chemico-astronomical investigations in the prosecution of which he has ever since been winning for himself the highest distinction. A couple of years after he had begun familiarising himself with the manipulation of the Spectroscope, he had already, as may be seen on turning to the "Philosophical Transactions" of 1864, succeeded in mapping out with wonderful care the spectra of no less than twenty-six of the chemical elements. Later on, in association with his friend Dr. Miller, he had by bringing side by side into contrast with each other the spectra of as many as fifty of the fixed stars, and the spectra of now one, now another, of the terrestrial elements, led the way to some most startling revelations—showing more clearly even than Newton had divined, or Pope had imagined, that—

"All are but parts of one stupendous whole."

Scrutinizing the spectra of the comets with peculiar care, he not only made clear the fact that they are essentially different in every respect from the spectrum of the Sun, but proved to demonstration that Winnecke's comet was nothing more or less than carbon in a state of incandescence. Drawing in nebular light from the farthest observable abysses of space, he made plain, from the circumstance of their showing only a few bright lines in the Spectroscope, that those mysterious sheeny lights in the heavens, the nebulæ, are nothing more than heated matter in a gaseous condition.

In some respects the most wonderful of all Dr. Huggins' achievements in the way of applying spectroscopic research to the enhancement of our astronomic knowledge is recognisable in the fact of his having determined with unerring precision the proper motion of several of these almost infinitely remote heavenly bodies which are only nominally fixed stars, and which lie in the outer depths of space at hardly conceivable distances beyond the limits of the solar system. This supreme attestation of his mastery alike of astronomy and Spectrum Analysis was arrived at purely through his having observed the displacement of the dark lines in the spectrum derived from the mere pin-point twinkle of one of those bewilderingly remote luminaries.

So remote indeed are the fixed stars, that the slender shaft of light received from them, and which come to us across such immeasurable abysses of the universe, can only be opened out into a spectrum by being passed through a cylindrical lens placed in the focus of the object-glass immediately in front of the slit. Otherwise than by means of some such exceptional arrangement, the image obtained from it through the prism would have been the merest, thinnest line, without any sufficient breadth on which the spectral threads, whether dark or light, could have been distinguishable. Beyond this, the dispersive powers of the Spectroscope thus applied to the examination of the fixed stars were ensured by the employment of two prisms of especially dense glass, the spectrum thus revealed being viewed through a telescope of particularly short focal length.

This telescope, moreover, was cunningly driven by clockwork throughout the period of scrutiny, so as to ensure to the star, so far as the earth's revolution upon its axis was concerned, as nearly as possible a stationary position upon the field of the Spectroscope. Examining thus the brightest and also one of the nearest of the fixed stars, the glorious dog-star Sirius, Dr. Huggins discovered, purely through the displacement of the delicate lines upon its spectrum, that it is receding from us at the rate of twenty-six or twenty-seven miles a second, widening the gulf between the solar system and itself every year by an additional interval of a thousand millions of miles. Although Sirius, as has been said, is one of the nearest of the fixed stars, its distance from this earth is so enormous that its light reaches us—light travelling always, remember, at the rate of 188,000 miles a second—only after the lapse of

Fig 80 —Star Spectroscope

twenty years! In eight minutes light flits to us from the Sun across a gap of 91,000,000 miles. Conceive for an instant, therefore, what the gigantic nature of the gap must be which intervenes between Sirius and ourselves, when it takes absolutely twenty years for the arrowy shaft of light, speeding onwards all the while at that bewildering pace, to come at last last within the range of our vision. Years ago Sir John Herschel, when endeavouing to afford some proximate idea of the awful abyss that divides the solar system from even the nearest of the fixed stars, after symbolizing the Sun as a ball two feet in diameter and the Earth as a pea revolving round it at a distance of 215 feet, observed that Sirius would have to be regarded as removed from even such tiny models of the Sun and the Earth by a space of at least some forty thousand miles.

Nevertheless, in spite of the appalling remoteness of Sirius, we know for certain in its regard, thanks to the profound analysis of its magnificent spectrum by Dr. Huggins, that its orb contains vast quantities of sodium and magnesium, that its atmosphere abounds in hydrogen, and that though still to this hour the brightest of the fixed stars it has been receding incessantly from the solar system at the rate of nearly thirty miles a second during the lapse of centuries upon centuries. Other stars there are, however, at absolutely unmeasurable distances, in regard to which, through the agency of the Spectroscope, kindred facts have been brought to our knowledge. Aldebaran, for example, a glorious ruby-red star, sparkling upon us from an incalculable distance, has, notwithstanding, made clear to us through the tell-tale lines upon its spectrum, that it contains an abundance of hydrogen gas as well as of the vapours, among other metallic substances, of iron, calcium, sodium, and magnesium.

Wonderful as had been the astronomic revelations made by the telescope during the last two centuries, they have been surpassed in our own day in a marvellous manner by those which have been so astoundingly arrived at through the subtle agency of the Spectroscope. Remembering that the pupil of the eye is no more than one-fifth of an inch in breadth, it can hardly be matter for surprise that sight should have found itself so immensely aided when larger volumes of light were gathered up into a focus for its advantage by a lens two or three inches in diameter. Hence upon Galileo constructing his first telescope, though it was but the merest tube, that he could poise with ease in his two hands and direct whithersoever he pleased towards the heavens—all he gazed upon through that rude instrument expanded to his view at once appreciably, and was brought to view with surprising distinctness. Mountains and valleys were then rendered visible for the first time in the Moon, spots were beheld in the Sun, the vast orb of Jupiter and the magnificent rings of Saturn were disclosed, the red continents, the green oceans, and the polar snows of Mars were brought with startling clearness within sight of the wonder-stricken astronomer.

If so much was accomplished by the mere hand-glass of the Tuscan philosopher, it can be no matter for surprise at all that, with the help of Sir William Herschel's reflecting telescope, not a few inches merely but four feet in diameter, sight was enabled to penetrate

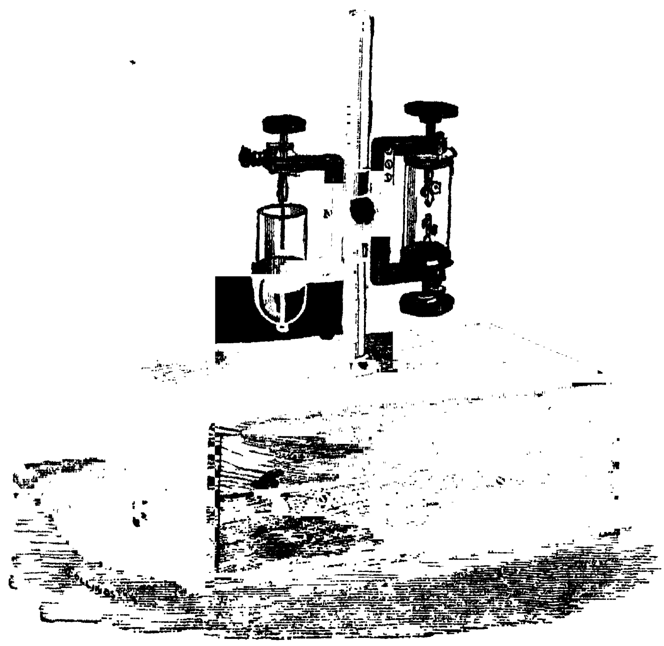

Fig 81 —Apparatus for Spark Spectra

further than ever and with astonishing keenness into the depths of the universe. When, however, Lord Rosse, going a giant's step further, erected his enormous tube at Parsonstown, with its weird speculum six feet in diameter, whereby the universe is augmented no less than 150,000,000 times, the limit might have been supposed to have been reached. Thus far it might have been thought but no farther could man hope to go in his endeavour to gauge the infinite abysses of space opened out to his observation. Beyond all this, however, as endowing him with a perfectly reliable means for immensely enhancing his knowledge, optical science and chemical science have together brought to his aid the marvellous Spectroscope. Possessing it, he can, by

Fig. 82.—Miniature Direct Vision Spectroscope.

merely catching a ray of light from one of the remotest orbs in space, and then unravelling it, read off—yes, literally *read in between the lines of the spectrum*—a number of perfectly reliable facts as to the physical constitution of a Sun so far removed that its magnificence has been dwindled down by distance to the merest speck.

Amazing though the revelations already made by means of the Spectroscope undoubtedly are, there can be no question whatever but that this new-born science of Spectrum Analysis, a science the existence of which dates but from yesterday, is as yet but in its infancy. Who can forecast, who can even remotely conjecture what may yet be the fruits of its development? So to speak, the two infinitudes, the infinitely small and the infinitely great, are open before it for its investigation.

With the Micro-Spectroscope of Sorby and Browning, an instrument in which the Microscope and the Spectroscope are brought with an almost magical effect into combination, the smallest object, the smallest portion of an object, nay, the very minutest particle may be subjected to a scrutiny from the searching character of which there is no escape whatever. Through its agency it is no extravagance at all to say that the secrets of a conscience might if the occasion for it should arise be unerringly revealed. In proof of this it will be enough to say that, with the aid of the Micro-Spectroscope, the thousandth part of a grain of blood is instantly detectable from the unmistakably dark bands revealed by its spectrum. So subtle in fact, is the operation of the Spectroscope, pure and simple, that is without its power being enhanced by the supplementary aid of the microscope, that the smallest possible particle of such a readily obtainable substance as common salt, say $\frac{1}{100000000}$ of a grain reveals itself in the twinkling of an eye by two intense yellow lines close together; such another atom as the minutest particle of lithium betraying itself by two more widely separated lines, one of a vivid red, the other of a dim yellow, and so on. Calcium discloses its existence by 75 lines in its spectrum; iron by 60 bright lines arranged in a peculiar way; and so on, again, through the whole half-hundred of the metallic elements.

Bearing in recollection Douglas Jerrold's droll order in the tavern, "Here, waiter, bring me a bottle of old port

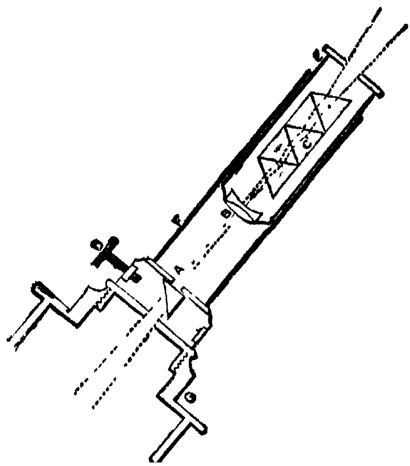

Fig 83.—Section of Micro-Spectroscope.

—not elder port!" it is satisfactory to know that from the absorption bands revealed by the spectra of different kinds of so-called port-wine, adulteration of it in any way, such as with log-wood, may be easily enough detected.

As pretty an experiment as any that can be tried in the Spectroscope is one suggested by Dr. Henry Roscoe, the translator of Kirchhoff,—to wit, the moistening of the mere ash of a cigar with hydrochloric acid, and then after fusing a bead of it into a platinum wire holding the latter in the flame of a gas-jet known as the Bunsen burner, when there will be at once revealed in its spectrum all the principal lines of sodium lithium, calcium, and potassium. As a matter of course the Bunsen burner should always be placed at such times exactly in front of the chink made by the

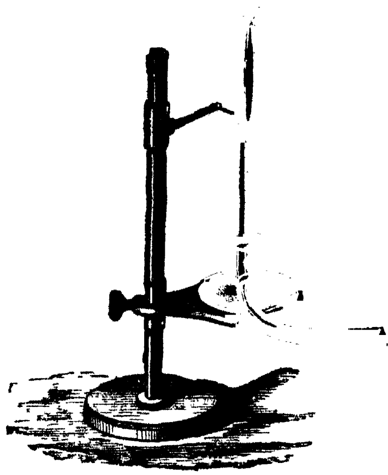

Fig. 84.—A Bunsen Burner on Stand.

knife edges, while the loop of wire attached to a convenient support should be brought to the front-edge of the flame, so that the glint of it may be cast clean through the slit into the spectroscope.

Among the various uses to which Spectrum Analysis has been applied, there is one which, by right of its results, gives large promise that the new science must later on prove of the greatest possible service to practical metallurgy. Allusion is here made to its successful employment in determining the precise moment in the Bessemer process for transforming iron into steel by blowing air through it when it has become thoroughly molten in its cupola furnaces—that exact instant in fact when the white-cast or specular iron,

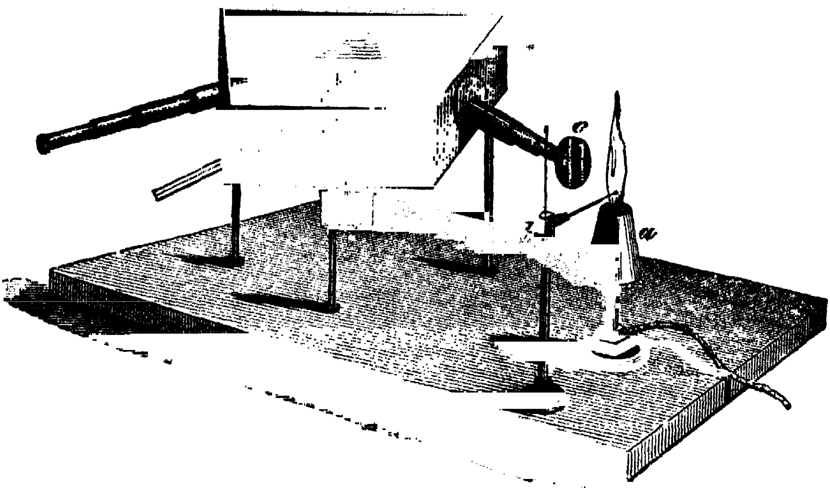

Fig. 85.—Bunsen's Apparatus for Viewing the Spectra of Flames.

technically known as spiegeleisen, ought to be added, at the very crisis when the decarbonizing operation closed. Important as such applications of the astonishing power of the Spectroscope undoubtedly are, however they shrink into absolute nothingness when contrasted with those which evidence the instrument's sublime capacity for piercing the depths of the awful universe around us, and for laying bare, so far at least as their physical constitution is concerned, the secrets hitherto surrounding the myriad worlds which are circling like golden star-dust in the illimitable ocean of immensity.

Through the investigations of Mr. Norman Lockyer alone, an extraordinary amount of knowledge has been already acquired as to the actual state of things in the Sun as disclosed by the intervention of the Spectroscope. According to the revelations thus made through spectrum analysis as to the condition of our own great central luminary, it would now seem to be undeniable that around the Sun, though at an immense distance from the orb, there is a cooler atmosphere, whence comes in fact that circle of light or Corona as it is called which visibly radiates into space in all directions round the hidden sphere at the time of a total solar eclipse. Immediately below this cooler atmosphere and consequently nearer to the sun, there is now known to be a chromosphere, as it is termed, of incandescent hydrogen, with intensely glowing vapours of calcium and magnesium of such enormous volume and in such stupendous turmoil that red bursts of flaming hydrogen have been seen to rise, within a few minutes' interval, to a height of twenty-seven thousand miles! Below the chromosphere and yet nearer to the Sun are vast quantities of metallic vapours, such as sodium, iron, zinc, copper and the six other elements already enumerated as having been identified as in existence there through the unmistakable evidence of the dark lines in the Solar Spectrum.

This is what Mr. Norman Lockyer designated the reversing layer, from its transforming into dark lines by absorption, portions of the sunlight shot through it, which sunlight must otherwise, but for that absorption,

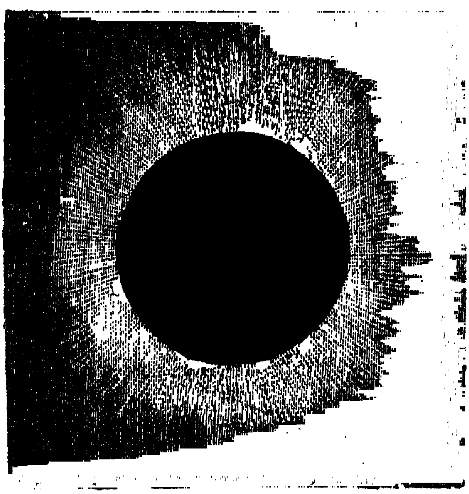

Fig. 86.—The Sun's Corona.

have been uniformly of a dazzling brightness. Underneath the reversing layer is the intensely heated matter, solid or liquid, which, known as the photosphere, gives off the light thus fortunately robbed of its luminous qualities in passing outwards—fortunately because from the very fact of there being these non-luminous lines, a key has been obtained to the otherwise hidden mystery of the sun's physical constitution.

Thanks to the revelations of the Spectroscope, not only do we know for an absolute certainty facts such as these in regard to the centre of our own system, as well as in regard to the planets generally and their satellites, but—inconceivable millions upon millions of miles beyond its outermost known orbit, that of Neptune,—in regard to those countless other suns, the so-called fixed stars, scattered in bewildering profusion through the boundless abysses of the universe. Already Spectrum Analysis has made clear to us, not merely that in one direction of the heavens Sirius is speeding away from us at the rate of nearly thirty miles a second, but that similarly in another direction, Arcturus is approaching us yet more swiftly; that is, at the rate of actually fifty five miles per second.

Beyond even this, the yet more astounding fact has been realized to us that the whole solar system—the sun accompanied by its attendant planets and their moons, and the planetoids and the comets—is bodily moving on at the rate of 150,000,000 miles a year towards a particular point in the constellation Hercules, the centre of the sun's orbit being, it is calculated, the chief star in the Pleiades, Alcyone. When facts like these have been brought to light by Spectrum Analysis within so brief an interval from the date of its discovery as a science, no possible limit can surely be put to the range of its future development. Knowing precisely what this new Wonder of the World is, seeing how subtly it acts, and remembering from what incalculable distances it derives its information, one can hardly help feeling that in the hands of an astronomic philosopher the Spectroscope is something more than an optical instrument—it is a talisman.

Fig. 87.—Celestial Cynosures for Spectrum Analysis.

VI.—THE ELECTRIC LIGHT.

"Vital spark of heavenly flame!"—ALEXANDER POPE.

DURING the early years of this century, before either gas or the electric light had been dreamt of, our streets were lit with oil lamps and our houses with candles. The latter were wax merely in the statelier mansions, but were elsewhere either dips or moulds of tallow, the wicks of which required incessant trimming with the help of a pair of snuffers. It was not indeed, until 1844, when composites were first manufactured, that candles ceased to require snuffing, and when the hitherto familiar snuffers and snuffer-tray finally disappeared. Until a very few years before that, artificial light for domestic purposes was alone procurable in every household, day by day, through a tedious and rather complicated process, and with the aid of the most primitive appliances, These consisted of a flint and steel, with a tinderbox and matches, accurately enough represented in the accompanying wood-cut.

A shower of sparks having been struck out by bringing the flint and steel into collision immediately over the open tinder-box—directly one of these sparks caught in the tinder it was encouraged to smoulder by blowing upon it, when, upon touching the glowing portion with the point of one of the matches, previously

Fig. 88.—Candle (A) Flint (B), Steel (C), Matches (D), Tinder-Box (E).

dipped in sulphur, the latter at once sprang into flame and the candle could be ignited. The contrivance thus used habitually in our kitchens and bedrooms but little more than a generation back, was almost as primitive and tedious as the Indian mode of obtaining fire from dry wood by friction, as indicated by the illustration overleaf.

Nearly thirty years of the nineteenth century had elapsed, indeed, before the first friction matches were contrived by John Walker, a druggist of Stockton-on-Tees. These, known for awhile as Congreves, were merely wooden splints coated with sulphur and tipped with a mixture of gum, chlorate of potash and sulphide of antimony. Drawn through a folded piece of glass-paper, they produced ignition. In 1834, however, the congreve was entirely superseded by the now world-famous Lucifer Match, the tip of which, being a combination of chlorate of potash and sulphuret of antimony, was stung into flame on being rubbed across a piece of emery paper. In the end, phosphorus and chlorate of potash becoming the chosen ingredients, a perfecting touch was given to the invention by Lundström of Sweden who, in 1855, hit upon the happy idea of the Safety Matches—matches, that is, which ignite only when rubbed on the prepared surface of the box holding them, that surface, and not the matches themselves, containing the phosphorus required for their ignition.

Long before the friction matches had come to be thus gradually perfected, the means of illumination employed among us, both in-doors and out-of-doors, were of the rudest and simplest character imaginable. Far more recently than is generally supposed, torches or flambeaux were carried about after night-fall in places of fashionable resort, while rushes dipped in tallow were burnt in many well-to-do houses. "Pickwick," in its serial form, it should be borne in mind, was not yet completed when her Majesty Queen Victoria came to the throne, and the readers of "Pickwick," will perfectly well remember the link-boy in the famous scene where Mr. Winkle is entering Mrs. Dowler's sedan-chair in the Crescent at Bath. And no less clearly will he bear in recollection the equally famous scene of Mr. Pickwick in the double-bodded room, into which the middle-aged lady in the yellow curl-papers "brought a rush-light and shade with her which, with praiseworthy precaution against fire, she stationed in a basin on the floor, where it glimmered away, like a gigantic lighthouse in a particularly small piece of water."

Apart from such old-world means of illumination as these, an entirely different source of light began to assert itself shortly after the dawn of the present century. As far back, it is true, as in the year 1739, Dr. Clayton had described in the Philosophic Transactions the luminous power of carburetted hydrogen—the inflammable aërial fluid evolved by the combustion of coal. In 1792 the effect of this had been tried by Murdoch in Cornwall. Half-a-dozen years afterwards, in 1798, the same thing had been tested upon a larger scale at Boulton and Watt's foundry in Birmingham. In London, however, gas was unheard of, as an illuminating force, until 1803, when Frederick Albert Winsor, a German, lit up the Lyceum Theatre with it, purely as a scientific experiment. On the 28th January, 1807, Pall Mall, and on the 16th August, in the same year, Golden Lane were lighted by the same agency. Between 1814 and 1820 the metropolis generally was, bit by bit, similarly illuminated. Since then so astounding has been the advance made by this system of lighting our public thoroughfares that it is calculated there are, now, underlying the capital, at the very lowest computation, two thousand miles of gaspipes! An estimate hardly less astonishing in its way has been made in regard to frictional matches, namely that in Europe twelve hundred tons of phosphorus are annually consumed (chiefly amongst ourselves) in their manufacture—300,000,000 matches being daily made in England, the yearly value of which is at least £1,500,000.

Yet, wonderful though the transformation is which has thus been accomplished in more than one of our great industries, in our search after light of a cheap, accessible, and brilliant character, the glory of carburetted hydrogen gas would seem to be at last upon the eve of not only being seriously rivalled, but altogether outshone as an illuminating power by the far more marvellous agency of electricity.

According to the old Arabian tale, whenever Aladdin rubbed the wonderful lamp, a Genie of stupendous might instantaneously appeared in answer to his summons, saying, "What wouldst thou have? I am ready to obey thee as thy slave, and the slave of all those who have that lamp in their hands; I and the other slaves of the lamp."

If we remember for a moment that the most vivid of all artificial lights—that derived from electricity—is in reality evolved from rotatory and therefore frictional motion, caused (it matters little how) by horse or hand labour, by the action of a windmill, of a water-wheel, or of a steam engine, it seems actually as if the electric light, which was brought to perfection, so to speak, only yesterday, had been symbolically foretold centuries ago in that old-world story of Aladdin.

Called into existence by the mere attrition of a revolving wheel, the Genie of Electricity performs around us now continually, as matters of every day occurrence, wonders that, within the recognition of all, are far beyond the wildest dreams of the oriental fabulist. While, thanks to the fact of its powers under certain aspects being transmissible through insulated wires to any distance—to the opposite shores of an ocean, or to the furthest extremities of a continent,—it can achieve many of its greatest marvels hundreds, nay thousands, of miles away with precisely the same facility as in the next street or in the next apartment.

A wonder-producing servant of all work, it obeys our behests alike in home, field, and factory. It ploughs the land, it sows the corn, it drives the harrow. It reaps, threshes, and winnows the grain, which it afterwards grinds into powder. It twirls the spit in the kitchen, the lathe in the workshop, and the sewing machine in the house-room. It can so regulate the clocks of a whole city that every pendulum shall beat with the same identical vibration. Obedient to command, it can be employed even to hasten the ripening in early summer of our apricots and nectarines. And beyond all this—and how much more!—the Genie of Electricity, whenever it is duly summoned, that is precisely in the same way as the Genie of Aladdin's Wonderful Lamp ("Aye, there's the rub!") reveals its presence upon the instant by producing a light of the most dazzling radiance.

As early in the present century as 1813 Sir Humphry Davy was the first to discover that the terminal wires of an electric battery—providing each were tipped beforehand with a charcoal point—upon their being first brought together and then slightly drawn apart, revealed between them an arc of light capable of development into all but blinding magnificence. Upon the occasion of his originally demonstrating this astounding fact—which it is interesting to remember that he did with the aid of 2,000 zinc and copper elements—he may be said, very literally, to have surpassed, in an electrifying manner, the mythical achievement of Prometheus. For, instead of having to soar

Fig 90.—Portrait of Sir Humphry Davy

into the empyrean for the purpose of bringing back thence, upon the tip of a hollow tube or ferula, a tongue of flame stolen from the heavens, Davy, while yet no more than a young philosophic experimentalist, found himself enabled, in the twinkling of an eye, by a mere turn of the hand, to conjure it into existence within arm's reach of him, in the laboratory of the Royal Institution.

The phenomenon thus revealed, in fact, is neither more nor less than the luminous effect of the electric current which, in passing through the air from point to point, causes intense heat and the most vivid illumination. So intense is the heat, indeed, that if the wires, unprotected by the carbon, were brought together and then slightly drawn apart, they would rapidly melt away and disappear.

Guarded, however, by that curious deposit which is found in the heads of gas retorts and which is known as hard gas carbon—a substance that may be either cut into pencils or reduced to powder and then compressed to whatever shape may be required—the terminals, while maintaining a high conducting power, remain infusible even under the fierce heat of the electric current. So effectually, indeed, are they screened from harm by their carbon sheaths, that they know no detriment whatever when, after momentarily touching one another and being then withdrawn apart to the distance of about the eighth of an inch, the electric arc appears between them in the form of a pure white light of such piercing splendour that it is absolutely intolerable to the naked eye.

Examined safely through coloured glass, this fierce light, it will then be perceived, emanates chiefly from the carbons which are glowing through and through with the intensest white heat, but partially also from a flame which connects and in a great measure also envelopes the two terminals. This flame in reality

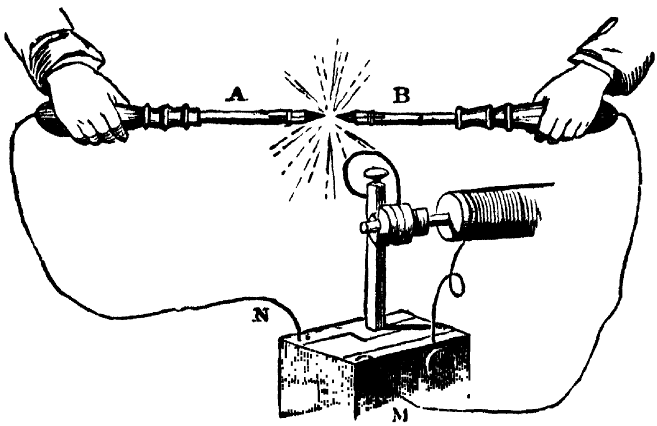

Fig. 91.—Magneto-Electric Spark between two Carbon Points.

consists of infinitesimal particles of carbon in a state of incandescence, and which are at the same time in rapid motion in myriads from one terminal to the other. Their visible drift, besides, is invariably from the positive or active, to the negative or passive pole of the battery—the former, so long as the electric current is flowing, being always the more intensely heated of the two: as is shown, immediately upon the stoppage of the electric current, by the fact of the positive carbon remaining red hot long after the negative has ceased to give any sign of having been recently in a state of ignition.

It should be remarked, however, that although the electric-flame is undoubtedly attributable to the combustion of the myriad microscopic particles of carbon which are perpetually flickering across from one terminal to the other, the electric light is mainly produced by the bringing of the solid substance of the carbons themselves into a condition of intense white heat. That it is so, is clearly demonstrated by the fact that it burns with a slightly diminished splendour under water, or oil, or any other non-conducting liquid, but on the other hand with a greatly intensified brilliance whenever it is revealed in a vacuum. So long, moreover, as the electric current is passing between the terminals, the flying atoms of white hot carbon projected from the positive pole, it should be remarked, are some of them consumed on the way, while others crossing over intact are deposited on the negative pole. Hence, indeed, the positive carbon-point, by reason of the constant carrying away from it of its incandescent particles, assumes after a while a scooped out or indented appearance, while upon the other hand the negative carbon-point, because of the incessant accumulation upon it of these infinitesimal atoms gradually acquires a more protuberant aspect.

The electric halo created by the rapid flight of these glowing molecules—a halo technically familiar as the Voltaic Arc—is, everything considered, the most intense and consuming artificial heat in any way producible. In it not only a platinum wire, but a clay tobacco-pipe melts away as rapidly as a stick of sealing wax does in

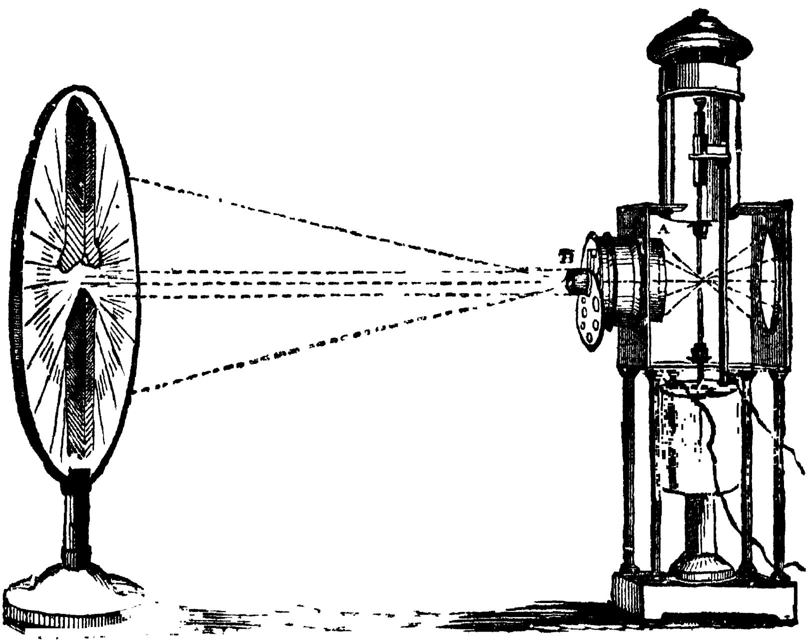

Fig. 92.—Enlarged Images of Carbon Points projected on a Screen.

the flame of a candle. Hence, indeed, from the minute but continual wear and tear that is thus going on in one of the two electrodes or carbon-points, so long as the electric current is flowing between them, it may be easily understood how—because of their very substance being wasted away and the distance between the two, however imperceptibly, widened—the time eventually arrives, of course, when they are too far apart for the flow of the electric current to be maintained. In order to insure its renewal, the only way at first appeared to be, the bringing of the carbon-points again together, and then once more withdrawing them from each other. Ingenious arrangements have, however, been contrived by means of which the carbon-points are enabled so to adjust themselves automatically that the required distance between them may be constantly preserved. Browning's Electric Regulator, shown on the next page, illustrates one of the most ingenious of these arrangements. In it, the upper carbon is held firmly in its place by an electro-magnet on the back part of the lamp. Whenever the space between the two carbons increases overmuch, the magnet, losing its power, allows the upper carbon to drop by its own weight, until it is again gripped by the magnet which is thus its automatic regulator.

If to Sir Humphry Davy must be accorded the credit of having first revealed the Electric Light, in 1813, by bringing the carbon-armed terminals of a battery into direct communication, the honour must be conceded to Lieut. Thomas Drummond of having, in 1826, produced the intensest light of any kind, down to that time known, by projecting a blow-pipe flame of mingled oxygen and hydrogen gases upon a ball of lime. This costly and rather perilous illuminating power was first of all famous by its equivalent titles as the Lime Light or the Drummond Light. Afterwards when magnesia and later on when zirconia came to be substituted for

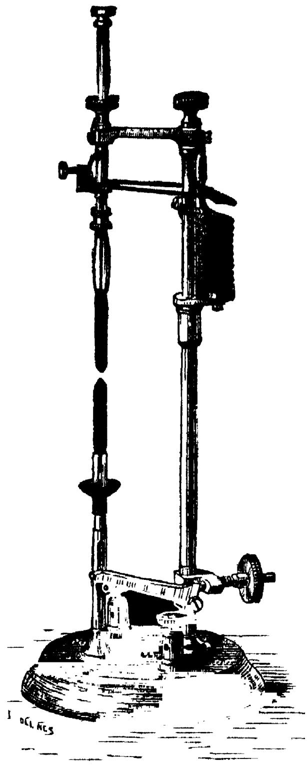

Fig 9 —Browning's Electric Regulator

lime, it was popular for a while as the Magnesia or the Zirconia Light—just as, ultimately, when a jet of oxygen was blown upon the lime ball, through a spirit flame, or through a coal gas flame, it was called, in the latte instance, the Oxy-Coal-Gas Light, and in the former the Oxy-Calcium Light. Spoken of generically, all these particular lights might perhaps be the most accurately defined as the Oxy-Hydrogen Light—the main peculiarity common to every one of them being, the combination at the moment of ignition of those two explosive gases. So dangerous is their employment, thus, that extraordinary care is at all times required in the manner of bringing them together—the risk of detonation through their premature mixture being, without such care, at any instant painfully imminent. At the best, however, even when they are most adroitly combined, these perilous elements have still the immense disadvantage of being exceedingly expensive. Yet, it must be allowed that the light produced in this way by the combustion of oxygen and hydrogen or of carburetted hydrogen upon a surface of lime, of magnesia, or of zirconia, is one of a peculiarly resplendent character. So magnificent, in truth, are its powers of irradiation that it is known to have been seen at a distance of 112 miles! While, so long did its reputation survive, that as recently as in 1861, it was, even then, still employed at the South Foreland lighthouse as a means of far-reaching illumination.

Not until sixteen years after the Lime Light had been thus given to the world by Lieut. Drummond, was any reasonable hope awakened that a time might come when electricity would in its turn be practically employed for lighting purposes. This was in 1842, when the first glimmering of that hope was caused by certain ingenious experiments adventured upon simultaneously by M. Deleuil and M. Archereau. Four years later, Greener's patent made evident, in 1846, the fact previously unknown, that a couple of pieces of carbon, separated from each other by a certain fixed distance and enclosed in an air-tight vessel from which the atmosphere had been abstracted, might be rendered luminous in the vacuum by passing through the wire at the core of each a current of galvanic electricity.

Between the confronting points of these two carbons —each shaped like a tiny cylinder—an uniform interval was constantly maintained by means of a clock-work arrangement, which steadily advanced the two in exact proportion to the rate at which they were being respectively consumed by the process of combustion. According to the more or less equable adjustment of this proportion between the consumption and the advance of the confronting carbon points, the light produced was continuous or intermittent. Two years after Greener's patent had been given to the world, a great number of similar contrivances were publicly displayed in Paris during the revolutionary excitement of 1848, conspicuous among which were those hit upon in rapid sequence by Staite, by Petrie, by Fizeau, and by Leon Foucault.

Seven years later, Jules Duboscq had on view in the

French capital during the exhibition of 1855, what was undoubtedly the most perfect electric lamp which up to that date had been anywhere constructed. Professor Tyndall, in the following year, 1856, first employed the electric light as a means of illustrating his lectures on colour at the Royal Institution. A couple of summers after this, the works of the then newly completed Westminster Bridge were revealed in a blaze of electric light by Watson to the astonishment of half London. Another twelvemonth had scarcely elapsed after this, when Professor Holmes, in 1859, amazed not merely half London, but the whole world, by devising the magneto-electric light, which to this day is recognizable as the most brilliant artificial light ever produced. Nearly thirty years previously Professor Faraday had prepared the way for this resplendent invention by his grand discovery, in 1831, of Electro-Magnetic Induction.

During the course of the very year in which Professor Holmes was demonstrating, thus, at Dover, the effective character of his arrangements for the production of the Magneto-Electric Light, there was issued from the press, and laid upon the table of both Houses of Parliament, on the 13th August, 1859, the now historical blue-book on Lighting by Electricity, which distinctly pronounced in regard to the electric light, that its economic subdivision was—to put the statement in one word—impossible.

Twenty-two years, all but two days, after that rather rash prophecy had been thus deliberately put upon record, there was issued from the press in Paris, on the 11th August, 1881, the official catalogue of the great Electric Exhibition in the French capital, through

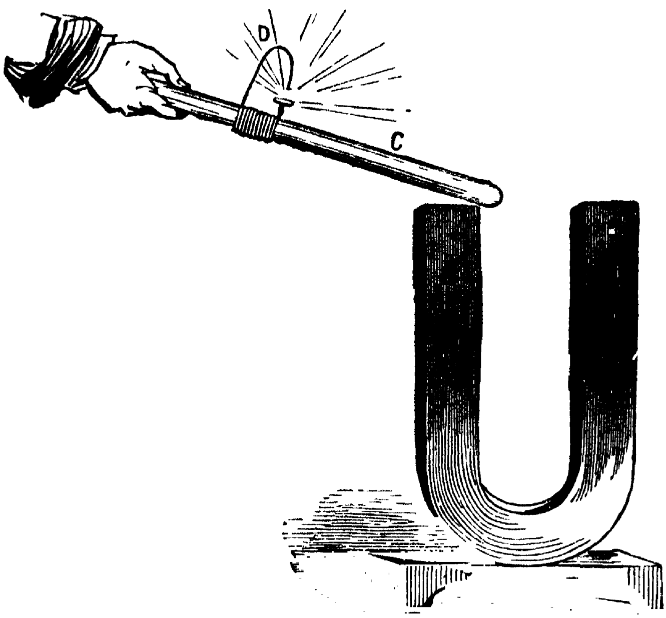

Fig. 94.—Magneto-Electiic Light.

which—as again in the following year, through the catalogue of the yet completer Electric Exhibition at Sydenham—its entire falsification was magnificently demonstrated.

Upon each of these memorable occasions, first, in 1881, in France, and afterwards, in 1882, in England—a radiant series of accomplished facts made clear to the comprehension of the whole world that within a very brief interval, thanks to a multitude of inventors, some really marvellous day-dreams had in rapid sequence been realized. Numerous though the successful experimentalists have been, however, through whose combined efforts so much has already been accomplished, there are two among them who, within the recognition of all, have won to themselves an especial pre-eminence. One of these is Mr. Swan, the Englishman. The other is the now world-famous American Professor, Thomas Alva Edison. To those two discoverers in particular the world at large is now mainly indebted for the immense and, as the blue-book of four and twenty years ago regarded it, the impossible boon of sub-divided Electric Lights.

Thousands upon thousands of electric lamps and electric generators have sprung into existence since Davy, in 1813, revealed the Electric Arc, and since Faraday, in 1831, revealed the great truth of Electro-Magnetic Induction.

These lamps and generators—the latter contrived to produce, the former to utilize, the electricity as an illuminating power—were, until the advent of Edison and Swan, in every instance employed exclusively in the fabrication of a large isolated burner or pharos. Thanks, however, in a very especial manner to those two adventurous innovators, the big lights, so long regarded as indivisible, have of late with the utmost facility and precision been, again and again, to almost any extent, divided and subdivided. What at the outset seemed only capable of being utilized upon a grand and costly scale, as the illuminator of a public square, for instance, or the banqueting hall of a palace, is to-day being brought within the reach (or in other words within the means) of the artizan in his house-room.

Broadly speaking, both electric lamps and electric generators, which are the two all-essential factors for electric lighting, may be considered, each of them, in turn, as separable into two distinct categories.

There are, for example, two readily distinguishable kinds of electric generators—those, namely, giving direct and those giving alternate currents; the latter being reversed, by the way, very many times in every second. Equally recognizable at a glance are the two great classes of electric lamps—to one or other of which every contrivance of the kind may be readily allotted. There are, for instance, the arc lamps in which the electric current passes through a guarded metallic conductor, and in which, as already explained, the circuit is broken between two carbon points—the luminous aërial bridge spanning the intervening space being produced chiefly by the heating of the carbon terminals, but partly also by the detached microscopic particles of white hot carbon flitting across incessantly from the positive pole to the negative. Essentially different from these are the incandescent lamps in which there is no disconnection whatever in the electric circuit, and in which, moreover, a solid conductor of feeble conductivity is heated by the current and rendered luminous. Here in point of fact—in these incandescent lamps the light is created solely by raising a fine thread of carbon to an extreme white heat by the simple process of passing through it either rapidly alternated currents or a direct and continuous current of electricity.

Whatever form electric generators may assume, they are one and all of them founded upon the principle first brought to light in 1831 by Michael Faraday. That principle, long known now by the term of electromotive force, reveals itself whenever a wire is so moved near the poles of a magnet as to traverse or cut its lines of force, consequent upon which a current of electricity is at once caused to flow from one extremity of the wire to the other! Aware of the mysterious tendency thus indicated, electricians have, now, for two score years together been doing their utmost to discover a solution for this most difficult problem — How to construct an electric generator which, with the smallest amount of waste, shall convert the largest amount of mechanical into electric action. M. de Meritens, for one, has striven to arrive at a satisfactory result in this matter by employing simultaneously a great many wonderfully powerful steel magnets — magnets so powerful as to be capable, each of them, of sustaining a dead weight of 150lbs. Generally speaking, however, experimentalists have used by preference electro-magnets made of soft iron, coiled around which are enormous lengths of insulated wire—the whole being rendered powerfully magnetic immediately there has been shot through the wire a sufficient quantity of electricity. Electro-magnets thus constructed have been found on the whole far more efficacious than the largest steel magnets ever produced.

Simultaneously, in 1866, Dr. (afterwards Sir William) Siemens and Sir Charles Wheatstone suggested the construction of electro-magnetic machines of this character. Discarding permanent magnets altogether, they demonstrated, by means of a series of splendidly successful experiments, that electro-magnets were far preferable. Wilde's was perhaps the earliest electric generator of this kind actually fabricated. But, foremost among all the direct current machines which have, since then, one after another, sprung rapidly into existence, are the five great classes of electric generators designed respectively by Gramme, Siemens, Brush, Bürgin, and Edison. Especial regard in several of these to the acceleration of the speed with which the machine works, has secured a marvellous enhancement of the electro-motive force thereby produced.

As affording the readiest means for ensuring that the same wire should be moved swiftly again and again past a given magnet, it soon became evidently advisable in the fabrication of these electric generators that it (the wire) should be attached to the circumference of a wheel which with the help of steam power

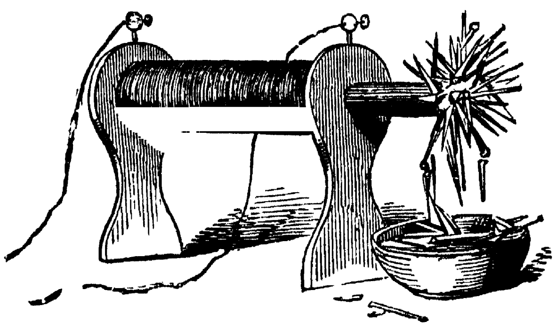

Fig. 95.—An Electric Current through a Coil of Wire, changing an Iron Rod into a Magnet.

could be caused to revolve with wonderful rapidity in the immediate neighbourhood of the poles of the magnet. By the invention of the Gramme machine especially a new impetus was given to electric lighting. A Lontin machine, which in many respects was not unlike the Gramme machine, but which has now altogether disappeared, was what first familiarized Londoners with the radiance of the electric light outside the Gaiety Theatre in the Strand. It was the

Gramme machine, however, which, later on, demonstrated upon a far larger scale, along the Thames Embankment, the adaptability of electricity to the lighting of our great thoroughfares. Then it was that there was employed for the first time upon a large scale a contrivance called the Distributor, whereby, instead of a single light, several lights were produced. In effecting this most desirable result, two Gramme machines were employed. One of them supplied the electric current which the other then distributed.

The American machine invented by Brush, is, everything considered, about the most powerful direct current generator ever constructed. Its revolving portion consists of a huge and ponderous iron wheel, into the rim of which, at regular intervals, are cut a number of deep notches. Insulated wire is then so wound in these notches that, as the result, a number of separate coils are ranged round the wheel's periphery. A single Brush machine, weighing two tons, and having a working power of thirty horses, was first seen at the Paris Exhibition, burning on one circuit forty arc lamps, each of which had a radiance equal to from 800 to 1000 candles. What was otherwise remarkable in regard to this gigantic generator was that the massiveness of its structure was about equalled by the exquisite finish of its adornment. Another Brush machine for moving wires past magnets, or, *vice versâ,* magnets past wires, according to option, vied with the one last mentioned in its colossal character. This was a generator contrived to produce one giant light for lighthouse illumination. In bulk four feet square, by five feet high, its insulated copper wires had a diameter of three-quarters of an inch, its carbon rods a diameter each of actually two and a-half inches—its illuminative power being the equivalent of 150,000 candles.

A Gramme machine has this striking peculiarity of structure—that its revolving portion is a wheel with a flat iron rim three inches in width, round which the insulated wire is wound in a rather singular manner. How, may be clearly enough indicated. Supposing you were to wind a length of whipcord round a flexible lath or strip of whalebone in a spiral coil, from one end of it to the other; and were afterwards to bend the flexible lath or whalebone into a ring, the form of the involutions on the flat rim of the wheel of the Gramme machine would be apparent. It is a ring so constructed that it revolves between the poles of two or four magnets, the poles of which, though wide, are not so wide as those of a Siemens' machine. One of the commonest Gramme machines now in use is the one the representation of which will be found overleaf. This is the experimental Gramme machine, in which, as its chief feature, the ring, just described, may be readily recognised. Another entirely different form of Gramme machine is one in which the ring is placed between electro-magnets, the latter being eight in number, fixed sometimes horizontally, as in fig. 97; sometimes vertically, as in fig. 98,

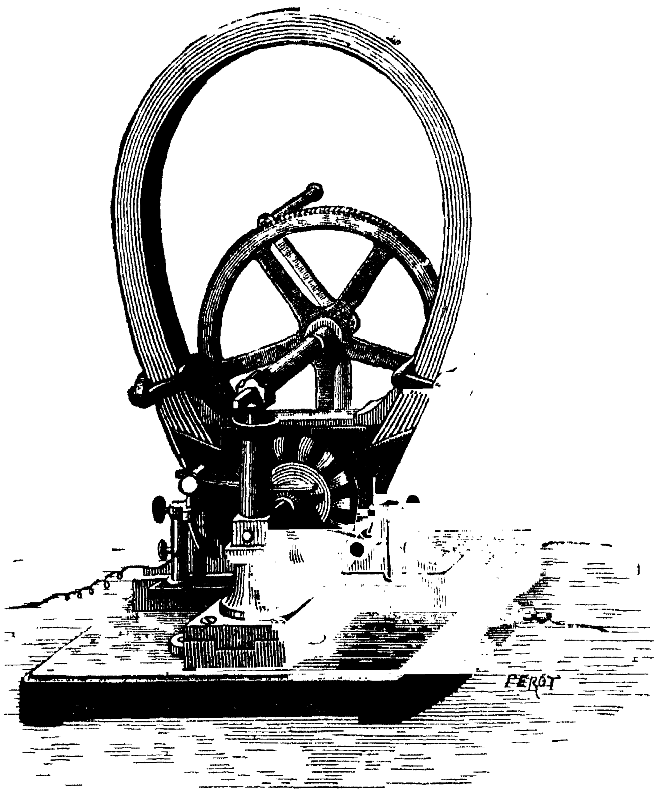

Fig. 96. Experimental Gramme Machine.

on page 298. Electric generators of this character, worked by a steam-engine, have an extraordinary electro-motive force.

A Russian engineer, of the name of Jablochkoff, may be said to have first awakened the attention of inventors, in 1876, to the applicability of magneto-electric power to the purposes of illumination. He did this by his ingenious discovery in that year of the

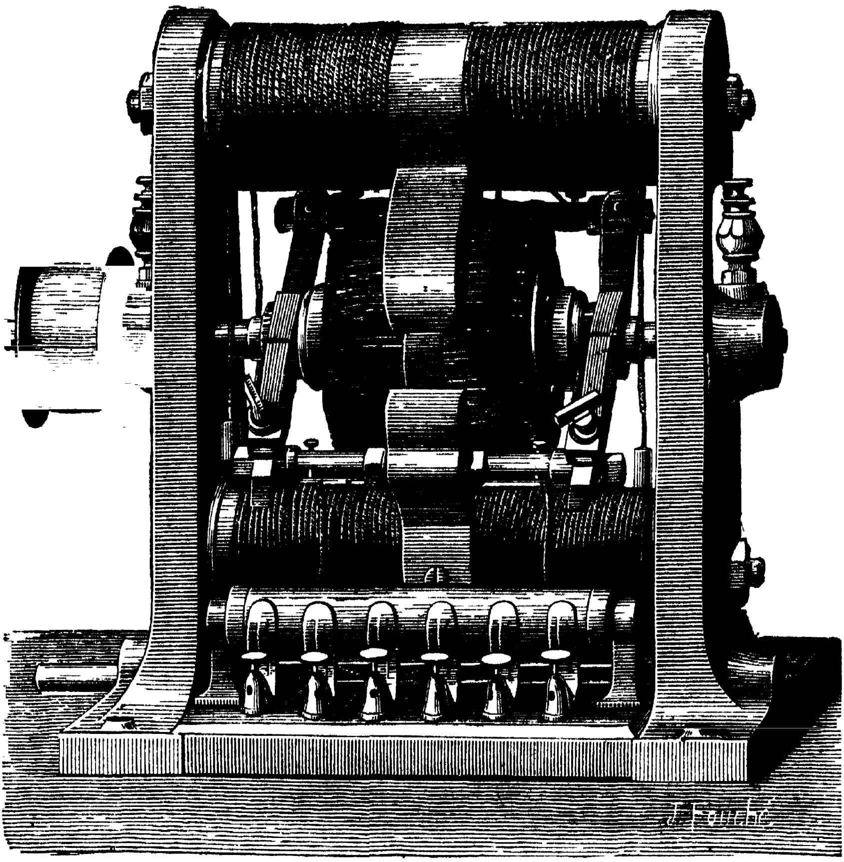

Fig. 97.—Gramme Machine, with Eight Horizontal Electro-Magnets.

Electric Candle, thenceforth identified with his own name. As the result of his contrivance, the two following years, 1877 and 1878, were remarkable for this, that within their compass more patents for electric

illumination were taken out than had ever before been enrolled at the Patent Office. Nor can this be in any way wondered at. For the Jablochkoff Candle by its extraordinary simplicity at once swept aside as valueless all the expensive and complicated regulators which had been previously employed. His contrivance, besides, was wonderfully well timed, seeing how many admirable, powerful, and almost perfect magneto-electric generators had already come to be constructed.

In the Jablochkoff Candle, as a glance at the woodcut overleaf will show upon the instant, the carbons› instead of confronting one another, are placed vertically, side by side, with a thin slip of plaster of Paris between them, keeping them apart from each other by a distance of three sixteenths of an inch. Seeing that the positive carbon always consumes at double the rate of the negative, it will be obvious that the application of a continuous current to the Jablochkoff candle would have caused the parallel carbons to burn down askew. Aware of this, the inventor, by applying alternate currents to the two—rendering each in turn, now positive, now negative—caused the pairs of carbons to burn steadily down after the manner of (what he called it) a candle.

Another description of electric candle in which the carbons were separated from each other by space, instead of being divided from one another, as in the

Jablochkoff Candle, by a strip of plaster of Paris, was devised by Wilde, of Manchester. In their construction, the points actually touched; but, so soon as the arc was established, they sprang apart in obedience to the action of a magnet, the electric light being, upon that, vividly maintained between the two electrodes

Fig. 99.—Jablochkoff Candle.

It was towards the end of 1879 that Edison in America and Swan in England, quite independently of each other, first produced practical systems of subdivision in electric lighting. Each, in carrying out his views, acted upon the same principle. In the hands of each, the lamp consisted of a fine filament or thread of carbon from 1-100th to 3-100ths of an inch in diameter, and having a length of from one-and-a-half to five inches—these delicate carbons being securely fixed inside a glass globe or bulb. So enclosed, the ends of the carbon were attached to metal wires, which, passing through the glass, were hermetically sealed in it. Immediately prior to their enclosure, every particle of air was carefully removed from the interior of the glass vessel, which was only then sealed up upon the instant of its being thus rendered a vacuum. These preliminaries having been scrupulously attended to, directly a current of electricity was sent, by means of the wires, through the carbon-thread, the latter became white hot—its glow, in the first experiments, yielding about as much light as there is in an ordinary gas jet. Filaments of carbon were eventually tried which were formed from one kind or another of vegetable fibre, such as bamboo, which had been carbonized by heating it to whiteness in a crucible carefully guarded from the atmosphere. In selecting the filament of carbon, the difficulty, from the very outset, was obviously to discover one fine enough to have a sufficiently high power of resistance, and which would last a considerable time without crumbling away under the wear and tear of the fierce heat to which it was subjected.

Edison's electric lamp has assumed to itself the elegant bulbous shape indicated in Fig. 100. Inside it at the time of its first formation—bent into horseshoe form, and attached at either extremity to the positive and negative platinum wires,—was a slender carbon produced from thin strips of the charred residuum of drawing-paper which had been placed in a mould and baked at a high temperature. Edison's electric lamp of later construction is no more than one-and-a-half inch in diameter. Inside it, arched under

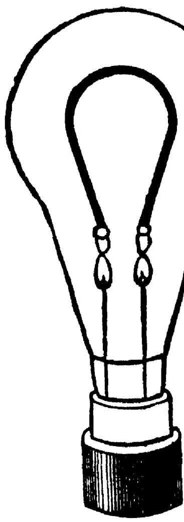

Fig. 100.—Edison's Electric Lamp.

the miniature dome of glass, is the apparently slight but tough filament of carbon, the ends of which are securely fastened to the two platinum wires. These are melted into glass tubes on to which, in its turn, has been carefully melted down the neck of the glass vessel itself. The whole structure, it should be added, is rendered scrupulously air-tight, every vestige of air before the lamp is brought into use being removed through a small aperture by means of air pumps of special construction. Otherwise, the least trace of air in the interior would, very rapidly indeed, cause the thread of carbon to perish and disappear. A current of electricity having been sent through the filament to drive all the gas in the carbon out, the last suction is made by the air-pump, and, while the filament is yet glowing, the globe is sealed up hermetically.

The original cost of an Edison lamp is no more than two shillings. It keeps in good working order for seven months together—before the breaking down of the filament. Even when it does break down, it can be replaced by a new one at the cost of one shilling; while its construction is so simple that it can be readily attached by any servant. So easy is the application of the electric light now, thanks to the young American wizard, that the current can be turned on and off by a brass tap exactly resembling, so far as its external appearance goes, the ordinary gas tap — with this advantage in favour of electricity, that, whereas the gas jet needs the striking of a match to light it, the electric lamp is a self-illuminator. Whenever, in Edison's direct current lamps, the filament breaks down, it is invariably found to do so close to the positive end of the horseshoe. But it is still worthier of notice that in his alternating current lamps, the wearing away being perfectly equal on both sides the carbon thread lasts much longer. Essentially different though the electric light and gas light are in themselves, the fact is nevertheless remarkable that in each the illuminating power arises directly from the ignition of carbon. How it is so in the instance of the electric light, has been already clearly explained. Enough if it be now added that the light of a gas flame is distinctly caused by the heating to whiteness or rather to yellowness of the particles of carbon afloat in the gas. So rapidly has electric lighting advanced in New York under the auspices of Edison, that whereas he began there at his Central Station in Pearl Street by opening, on the 5th of September, 1882, twenty miles of electric mains, the following year had not very far advanced before he was laying down five hundred miles of electric mains in the same great Empire City. His aim is to bring into every house, and into every room in every house, one of his pearl-like incandescent lamps, each of them being cheap, luminous, and manageable.

Simple though it is in its construction, Edison's electric lamp passes through no less than two hundred stages in the process of its manufacture. Yet, of these lamps, there are turned out every day in his factory, 10,000. Upon a less wholesale scale, but still with marvellous rapidity, he is turning out from his machine works, in another part of New York, dynamos, large and small, of the most skilled and solid manufacture. His laboratory is at Menlo Park, where, with a still youthful look, but with the hand and eye of a master, he conducts his scientific necromancy.

On Tuesday the 11th April, 1882, Professor Edison's representative then in London, Mr. Johnson, established, at 57, Holborn, a central station for supplying electricity, in this way, for lighting purposes, to the adjacent Viaduct and to the buildings in its immediate neighbourhood. Sufficient electro-motive force, to this end, was supplied, by means of two gigantic dynamos, to feed 2360 incandescent lamps, each of sixteen-candle power. The smaller of these two huge machines, weighing twenty-two tons, and resting, engine and all, upon a ponderous base of hollow iron, furnished light to exactly 1000 lamps. Its field magnets were twelve in number—its armature, the shaft of which was connected directly with the driving-wheel of the steam-engine, making as many as 350 revolutions in a minute. As for the larger dynamo, its dimensions may be readily inferred from the fact of its being enabled to drive as many as 1360 lamps altogether.

From Edison's central station in London, insulated wires are laid in mains under the street pavements—from which mains, sub-mains, or branch wires, also carefully insulated and enclosed in tubes, enter the buildings in which magneto-electricity is laid on as readily and effectively as gas or water. While it should be especially borne in mind that all the wires thus trailed under that portion of Holborn and its vicinity, are fitted with the patent fusible plug, which effectually prevents any possible risk of fire, from an excess of electricity passing along those metallic conductors, it is particularly worthy of note that Edison's system of electric lighting requires only a very low pressure current which in itself is perfectly harmless. Insomuch is this the case that one of Edison's wires may be handled with impunity, whereas it is instant death to touch one of those employed by the Brush or indeed by any of the other formidable arc systems of electric lighting, all of which use by necessity a high-pressure current.

Along the Holborn Viaduct, from Newgate Street to Holborn Circus, as many as 200 street lamps were brilliantly illuminated thus in the spring of 1882, from Edison's central station —175 more electric lamps being supplied thence to Dr. Parker's City Temple, and 160 more to the London, Chatham and Dover Railway Terminus. During that same year the Brush Light illuminated the great main thoroughfare of London from Cheapside to Blackfriars; the Lontin and the Siemens system each had a district allotted to it within which to make clear its relative excellence; while the Laing Light rendered Regent Street luminous under the driving power of a sixteen-horse steam-engine secreted in the zebra-striped wooden shed which for a while disfigured the open space between the Duke of York's column and the Guards' Memorial. At Sydenham, again, in that ever memorable year in the history of the electric light, a yet more concentrated demonstration was given of the respective merits of the different systems in the great International Electric Exhibition. There, high up in the roof of the Tropical department, the Brush Arc Light burnt resplendently with 150,000 candle power between a couple of carbons each two inches in diameter. There, at the south end of the Palace, shone the arc light of Dr. Siemens. Here, in the Chinese Court, was the electric light contrived by Crompton—yonder, in the Western Gallery, that of Hawkes—yonder, again, were the incandescent lamps of Lane Fox, while those of Edison lit up the whole of the North Nave.

An authoritative pronouncement in the Court of Appeal, on the 18th February, 1889, by the Lords Justices Cotton, Lindley, and Bowen, finally established Edison's claim to priority as the first inventor of the Sub-divided Incandescent Light by right of his memorable Carbon Filament Patent taken out in the November of 1879.

Reverting, however, to the Exhibition at Sydenham in 1882—perhaps the most interesting portions of it were the Eastern Gallery, which was set apart for the purposes of a grand telephonic demonstration, and the

Entertainment Court, in which were collected the numerous wonderful inventions of Professor Edison, each worked and explained with admirable lucidity by his agent Mr. Johnson.

Harmless lightning was there caught and set playing under that roof of glass and iron. Electric rollers were seen sorting bran from flour. Electric lamps burnt brightly under deep water. Electric tills were employed in which every separate payment was recorded. Electric telephones talked conversationally from all but incredible distances. Electric burglar-scarers and thief-detectors clicked and clanged inexorably in aid of the law. Electric ploughs were shewn at work ripping deep furrows in the soil. Electric clocks, cutting time very fine indeed, automatically regulated themselves to the merest fractions of seconds. Electric surgical instruments were displayed all but magically adapted for diagnosis and operations. Electric musical recorders were fitted on to pianofortes, which according to the vibration of the notes struck upon the keyboard jotted down on an endless ribbon of paper ruled with the stave lines any improvisation indulged in by the performer.

In aid of all these marvels and of many others yet more marvellous which were brought to view, in 1881, under the glare of the electric light, there has to be added that astounding support to electro-magnetic force which has brought within reach of the electrician his grand reserve of the secondary battery. More than twenty years prior to the great Electric Exhibition at Sydenham, Planté, in 1860, had hit upon his wonderful device of Electric Storage. His secondary pile consisted of two long plates of lead rolled together, with strips of gutta-percha between them to prevent their actual contact. Having placed this roll in a jar of diluted sulphuric acid, he then connected it with a couple of Grove or Bunsen cells, or, in other words, with a primary electric battery. Thereupon, very gradually, at first all but imperceptibly, a change began to take place in the rolled-up lead plates. The one by which the current from the primary battery entered, became, little by little, covered with a coating of peroxide of lead—caused by the action upon it of the oxygen liberated from the acid water. Remembering that the peroxide thus formed is powerfully electro-negative to the metallic lead of the other plate, and to the hydrogen accumulated by it,—it will be understood that when the cell has once arrived at this condition it has become capable of yielding an electric current. Planté found, during the course of his experiments, that long-sustained action of the primary battery, extending over several weeks, was imperatively requisite before the coating of the peroxide had become sufficiently thick to yield an appreciable result in the way of a strong electric current.

Twenty-one years after Planté's discovery of electric storage, M. Faure, by a very slight modification of his plan, immensely facilitated and strengthened its operation. This he accomplished by painting the lead plates with a mixture of acid and minium (otherwise red lead), so that Planté's tedious process of forming the peroxide was done away with completely—the improvised battery being strong enough to yield an electric current almost as soon as it was constructed. It has been, reasonably enough, pointed out that in both Planté's and Faure's cells the action is quite as much chemical as it is electrical, and that storage of energy would, perhaps, be a better name for it than storage of electricity. As a writer in the *Edinburgh* happily expressed it, the whole process is an ingenious piece of electro-chemical legerdemain.

Faure's secondary or condensing battery—in contradistinction to Planté's, already described,—consists of a couple of leaden plates, coated with red lead, covered with porous felt, and then rolled, each of them, into the shape of a spiral scroll. Thus rolled up, these two scrolls are placed side by side in a vessel of water slightly acidulated. In this manner, placed near one another but not in communication, they form a sort of inert or inactive voltaic pair. From each of the two scrolls a strip of lead is left projecting over the rim of the jar or vessel in which they are enclosed. These strips of lead furnish the means of completing a circuit connection between them and the poles of an ordinary voltaic battery. Directly a circuit has been thus rendered complete, a chemical action begins and a voltaic current is established through all the involutions of the two spiral plates. As the result of this, the red lead on the plate connected with the positive terminal is very soon fully oxidised, while the red lead on the plate connected with the negative terminal is, on the contrary, completely de-oxidised, or, in other words, reduced to the metallic condition. In this state the battery is said to be loaded. Sir William Thomson, indeed, has not unhappily likened the storing up of electricity thus to the winding-up of a clock!

The voltaic current, having changed all the red lead upon one plate into a peroxide of the metal, and having transformed the red lead upon the other into metallic lead, has in this way generated the store of—call it whichever you please—energy or electricity.

If, when it has arrived at this condition, the wires of the primary battery are disconnected with the leaden strips, the electric store is then securely retained or immured in the spiral scrolls for after use wherever or whenever it may be required. A Faure apparatus, weighing no more than 200 lbs., it has been calculated, gives storage thus for enough electric energy to perform the same amount of mechanical labour that might be accomplished in one hour by a horse. It is on record that during the earlier half of 1881 four leaden cases of this kind of condensed electricity were dispatched from M. Faure, at Paris, to Sir William Thomson at Glasgow. These four little cases, which were contained in a wooden box one foot square, after making that long journey of seventy-two hours in charge of a special messenger, it was found by Sir William Thomson, had enough force in it to lift 1,000,000 lbs. a foot high! Yet the whole apparatus weighed itself but seventy-five lbs., while each cell was a leaden cylinder of no more than five inches diameter and only ten inches high.

If the electric light may be compared, not inaptly, as it has been compared here, to the Genie of the Lamp in the history of Aladdin, electric storage may be likened, not inappropriately also, to the Genie of the Brass Pot in the Arabian tale of the Fisherman. While, to add to the wonder, Faure's secondary battery, charged with that potent reserve of electric power, can be carried about just as easily as the fisherman carried about the brass pot, and can be delivered at the house door quite as readily as a can of milk or a sack of coals. Out of those little rolled-up plates of lead a force can be summoned at pleasure which can work greater marvels than were ever dreamt of even by the imagination to which the world is indebted for the Arabian Nights Entertainments.

VII.—THE TELEPHONE,

WITH ITS CONGENERS, THE MICROPHONE AND PHONOGRAPH.

"Will speak with most miraculous organ."—SHAKSPEARE.

THAT two men, though separated from each other by the distance of a thousand miles—the one at New York, the other at Chicago—should nevertheless be able, with the greatest ease, to converse quite audibly with one another, across that enormous interval, through the agency of a metallic wire, would, even in this age of marvels, have been pronounced, only the other day, the wildest of impossibilities. Yet this is precisely what was done at the two places just named—the Empire City and the capital of central North America—on Sunday, the 25th March, 1883. And what perfects the wonder is this, that the apparatus attached to each end of the thousand miles of wire is so compact and so little complicated that it looks for all the world like nothing more important than the handle of a skipping-rope. So curiously simple also is it in its construction that, shortly after its invention was first announced, Professor Pepper delighted the boys of England by explaining how any intelligent urchin could make a perfect working model of the contrivance with such primitive appliances as a penny pop-gun glued into a wooden tooth-powder box. Such, in brief, to begin with, is the structural simplicity, such are among the astounding achievements of that last, and certainly not least, of the modern seven world wonders, the Telephone.

Yet marvellous though the Telephone is in itself, there have grown out of it two other discoveries, each of which is, if possible, still more astounding.

One of these so magnifies sound that it does for the ear what the microscope does for the eye. It renders loudly sonorous what would otherwise be inaudible, just as the microscope brings glaringly to view the invisible. Through its agency the delicate running of a fly can be heard like the tramping of a horse. And yet so readily can the contrivance be put together that the first one was actually built up by its inventor with no costlier materials than an empty match-box, a pen-holder, a bit of sealing-wax, and a morsel of string. This in one word is the Microphone.

As to the other chief outcome of the Telephone, it may surely be said to surpass even that, when it has been remarked that by merely talking into the mouthpiece of the little instrument, and at the same time revolving a cylinder, the words uttered are metallically recorded, and that then, upon merely shifting back to its original position the cylinder that has been set in rotation, and again revolving it, the words thus placed upon record are absolutely repeated by the apparatus itself with the clearest and distinctest articulation. Such, as a mere matter of fact, is the Phonograph.

Having prepared the way by these few sentences for what is to follow, it merely remains now to explain how it was, step by step, that this wonderful invention of the Telephone came to be perfected, and how, very soon afterwards, there blossomed out of it the Microphone and the Phonograph.

More than two hundred years ago Robert Hooke, the reputed inventor of the barometer, wrote, in 1667, with reference to the possibility of a whisper being rendered audible at the distance of a furlong, "I have by a distended wire propagated the sound to a considerable distance in an instant, or with as seemingly quick motion as that of light, at least incomparably quicker than that which at the same time was propagated through the air; and this not only in a straight line or direct, but in one bended at many angles." Exactly 200 years afterwards, in 1867, the little toy known as the string telephone was invented, as nearly as possible on Dr. Hooke's principle. At each extremity of the string was a cylinder of metal or cardboard, the inner end of which was closed by a tightly stretched membrane of parchment, having at its centre, held by a knot, the cord of communication.

With this simple contrivance two people, it was found, could readily converse even when 170 yards apart, provided always, of course, that the string were held taut between them, their whispers flying to and fro as the cylinder of each in turn was placed alternately at ear or mouth. Silk cord proved on experiment far preferable to hempen, but cotton as a rule was used instead of either. Thread telephones have, in fact, it is believed by some, been familiar in the nursery ever since 1860. Mere toys though these little instruments were, they happily had in their action a wonderful suggestiveness. Whoever spoke into one box, by the vibration of his voice caused the parchment membrane or diaphragm in it to vibrate. The vibrations of the diaphragm causing so many pulls upon the connecting thread, produced at its opposite extremity precisely similar vibrations in the other diaphragm, whereby the far-off whispers were distinctly repeated in the ear of the listener.

Obviously, therefore, if only some means could be found for throwing a diaphragm into motion at a distance—at any distance you please—so that its movements should correspond exactly with the movements of a diaphragm agitated by the voice of a speaker or singer, the original sounds, whatever might be the intervening distance, would be exactly reproduced. As early in the century as 1819 or 1820, however, Sir Charles Wheatstone, afterwards world-famous as the inventor of the electric telegraph, had contrived, with what was apparently a far more unwieldy medium than the metallic wire employed by Hooke, namely, with the vibrations of a deal rod, to transmit sound effectively in a wonderful manner from one distant story of a large building to another. With no less primitive agency than a deal rod he conveyed the sounds of a

Fig. 101.—Thread Telephone.

musical box from a cellar to one of the upper rooms of the building in which his ingenious arrangement was exhibited under the mysterious title of "The Enchanted Lyre." In the "Letters and Journals of Caroline Fox," of Penjerrick, edited by Horace Pym, and published in 1880, mention is made, under date 5 June, 1838, of an improvement upon this beautiful contrivance by its inventor. Caroline Fox, in fact, there speaks in her Diary of having just listened with wonder to the performance at King's College of "Professor Wheatstone's harp, or rather sounding board with additaments, which communicates with a piano two stories higher and receives the sound from it quite perfectly through a conducting wire!"

To this the editor of the work, by way of footnote (p. 30), puts the "Query: How far was this the origin of the Telephone?" Eighteen years before the "Magic Harp" was heard at King's College, however, as has been here shown, Wheatstone had already given promise of that portent of the coming telephone in his "Enchanted Lyre;" while, later on, it resulted in Wheatstone's "Telephonic Concert" at the now vanished Polytechnic Institution. There, as the accompanying illustration will clearly show, performers in the basement and sub-basement—the sounds produced by whom on the piano, violin, cornet à piston, and violoncello, were inaudible in the intermediate hall—were heard with the utmost distinctness above stairs in the public lecture-room.

From Hooke to Wheatstone, at rare intervals during the better part of two centuries, experiments had thus demonstrated that sound could, under certain circumstances, be readily transmitted to a distance through wire, thread, lath, or string, purely by means of those connecting lines being thrown into a state of sympathetic vibration. A subtler agency than had yet been dreamt of was at length, however, to come in aid of the experimentalists. The first medium employed in the transmission of sound—the metallic wire—was to be

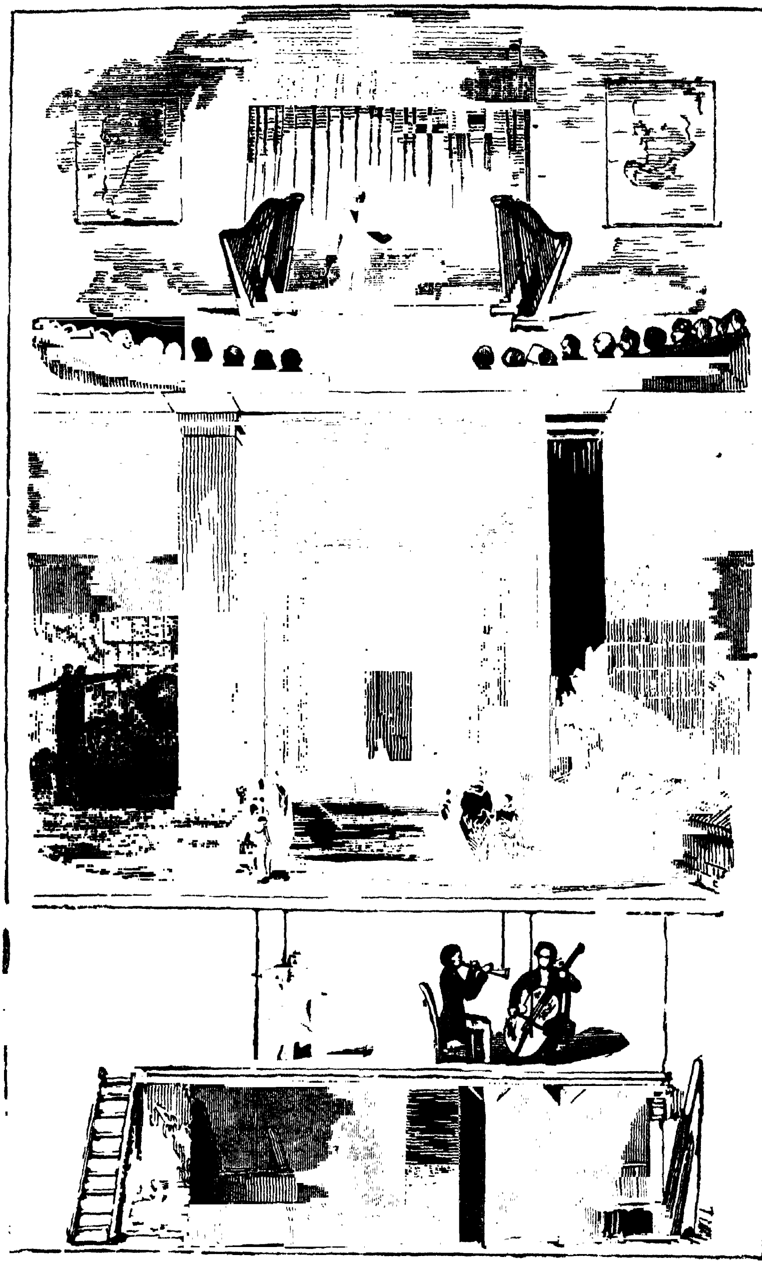

Fig 102 —Wheatstone's Telephonic Concert reverted to and thenceforth exclusively employed to that end as the channel of communication. It was to be so used from that time forward, however, not mechanically, so to speak, as a mere vibrating line, but, with a far subtler potentiality, as a thing, one might almost say, magnetically vitalized, as a line thrilling from end to end with electricity.

As a first step towards this result, an American named Page, in 1837, discovered what is now known as the Magnetic Tick. While he was in the act of magnetising and de-magnetising an iron bar by sending an electric current through the helix or coil of wire surrounding it, he found to his surprise that the operation resulted in an audible click. This phenomenon arose, as Wertheim soon afterwards proved, from an infinitesimal lengthening or shortening of the iron rod according as it was alternately magnetised and de-magnetised. Professor Joule even succeeded in demonstrating that the bar was thus elongated or the reverse each time by $\frac{1}{180000}$ of its whole length. By making and breaking the electric current with sufficient rapidity, or in other words by causing the magnetic tick to be repeated so many times in a second, a musical note was produced, whose pitch was higher according as the number of the repetitions were greater and swifter.

Out of this discovery there gradually grew up, in the lapse of years, a whole system of musical, or as they were called, Tone Telephones. De la Rive, of Geneva, was one of the first, in 1843, to give any appreciable advance to the transmitting of musical sounds thus by means of magneto-electricity. Ten years afterwards, in 1853, Count du Moncel, in his *Exposé des applications d'Electricite*, startled the world by describing M. Froment's apparatus for causing electricity to set metallic plates in vibration so as to render pianos, organs, and other musical instruments audible at a distance thereby producing what the theoretical inventor termed electric harmonics. His projected arrangement had not at that date, it is true, been anywhere put to the test, but it was rendered evident by his whole argument that its capacity for doing what he insisted it could do, admitted of the readiest demonstration.

In 1854, M. Charles Bourseul published some yet more startling predictions in a treatise through which he insisted upon the perfect feasibility of the electric transmission, not merely of musical sounds, but of articulate speech, his argument distinctly foreshadowing much of what has, since then, been actually accomplished. With far-reaching sagacity he insisted that, to effect the wonders he described as certain of being a little later on accomplished, nothing more was required than an electric battery, two vibrating discs, and a wire! Commenting upon this daring theorem of

M. Bourseul, it was, in no way extravagantly, remarked at the time by Mr. Preece, the well-known electrician of the Post Office, that the idea thus thrown out was magnificent.

On the 10th May, 1855, Wheatstone's Tone Telephone was so happily an accomplished fact that upon that afternoon Professor Pepper was lecturing upon it before the Queen at the Polytechnic Institution. In the following year, 1856, Pétrina of Prague more than justified the prediction put forth three years previously by the Count du Moncel (as made plain three years later on, in 1859, by the latter through the 4th volume of his *Exposé*,) to the effect that electro-magnetism would, indeed, one of these days come to the aid of pianos, organs, and other instruments, by enabling them to be played and heard at a distance. By a happy coincidence it was just at this time, in the winter of 1855-56, that M. Léon Scott of Martinville hit upon an invention which he called the Phonautograph, which realized at last for physicists what they had long been in search of, namely a means of actually registering sound. It consisted, this little contrivance of the Phonautograph, of a stretched piece of some delicate membrane, such as gold-beater skin, or caoutchouc, having attached to the outside of it a feather held lightly in contact with a blackened revolving cylinder. And according to the vibrations of the voice or instrument resounding above it, the vibrating membrane traced, with the feather attached to it, sinuous lines on the blackened cylinder as it revolved below. Originally designed by its inventor merely for the graphic representing of vibrations, it has since acquired for itself a value and interest of scarcely measurable importance, from the fact that it eventually proved to be the origin of the vibrating plate of the telephone.

By the 25th April, 1860, Philip Reiss of Friedrichsdorf had constructed the first partially articulating Telephone ever listened to, and the sound of which was likened by those who heard it to that of a child's penny trumpet. It was exhibited by its inventor at Frankfort-on-the-Maine, and its chief merit lay in the fact that its transmitter effectively controlled the number of electric contacts by the action of a vibrating diaphragm. A representation of the instrument is given on the next page

It consisted of a box, *A*, having a trumpet-shaped mouthpiece at its side. At the top of the box was a circular hole filled with a membrane or parchment diaphragm, *u*. In the centre of the diaphragm was a small piece of platinum, *p*, over which, but not touching it, was a metallic point, *m*. On singing into the mouthpiece, the parchment diaphragm vibrated, the piece of metal at its centre at each vibration touching the point suspended above it. According to the

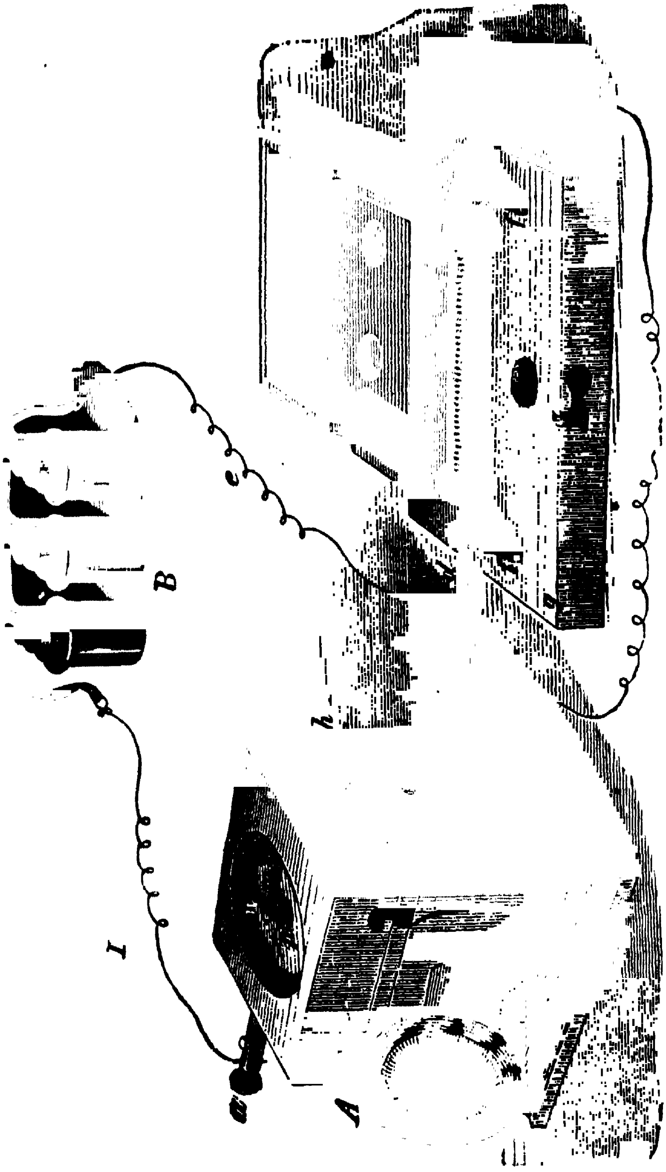

Fig. —Philip Reiss's Tele

number of vibrations in every given note articulated, a similar number of contacts were made. And both metal pieces being joined with the battery, *B*, and the line wire, *a*, these contacts being electrical, effected the magnetisation of the iron bar, *CC*, which, with its copper helix, formed the receiving instrument at the distant station. Later on, in 1868, this instrument was perfected by M. Vander Weyde.

Cromwell Varley, in 1870, produced an entirely different instrument in which the action of the commom tuning-fork was ingeniously employed to make and break the electric current. This, later on, was the first form of Telephone ever publicly exhibited in England, in which sounds were conveyed from any considerable distance. It was not until seven years had elapsed, however, that it overleaped the Thames and connected Surrey with Middlesex. One end of it being then placed in the Queen's Theatre, Long Acre, and the other in a transpontine music-hall, melodies performed in the latter were, on the 12th February, 1877, distinctly heard in the former by an astonished audience.

Meanwhile, four years after Cromwell Varley's first success, Elisha Gray of Chicago, in 1874, constructed an instrument of a somewhat similar character but considerably more effective in its operation. In it he employed a number of metal tubes like the reeds used in the building up of a harmonium, and the vents of which were similarly governed by pianoforte keys. These were so arranged that the electro-magnets at the distant station actuated similar reeds, and in this way the original sounds were accurately reproduced.

A sounding-board, or rather box, pierced with holes like the letter S, was an important part of the apparatus, imparting to it something of the resonance of a violin. Elisha Gray, in constructing this Musical Telephone, was led to do so by his recognition of the fact that the molecular motion which takes place in the magnetic coil and its armature under the influence of alternate magnetisation and demagnetisation, suffices to produce vibrations corresponding to the velocity of these alternations and to emit sounds which became audible when they were magnified by his perforated box or sounding-board.

To complete, here, what yet remains to be said about several other kinds of remarkable Musical or Tone Telephones, it may be added that conspicuous among these was the "Singing Cardcase" of MM. Pollard and Garnier, in which songs apparently issued from a kind of pocket-book. Whenever a vocalist at the other and distant end of the wire sang in front of the sender or mouthpiece of the apparatus, the condenser at the receiving end of the instrument emitted sounds like those of the hautboy or the violoncello. In the instance of Varley's musical telephone, the receiver was a drum of considerable dimensions, being, in fact, three or four feet in diameter. Within this, parallel to the membrane of the drum, was the condenser, which consisted of four separate sheets of tinfoil, divided from each other by some insulating material. Another receiver, invented by M. Bréquet, resembled a kind of tambourine. M. Badet, again, contrived one in which parchment was used stretched upon frames of resonant wood. Millar of Glasgow, whose telephonic arrangement conveyed musical sounds readily through a telegraph wire to a distance of 160 yards, employed drum-shaped discs variously made of wood, metal, or gutta-percha, having a wire invariably at their centre.

Heaviside and Nixon of Newcastle-upon-Tyne, who found that No. 4 of the English gauge was the most effective wire of all for telephonic purposes, employed discs ⅛ inch in thickness. With these, well stretched and motionless, it was possible to hear what was said at a distance of 230 yards. But Huntley, by using very thin iron diaphragms, and insulating the wire on glass supports, succeeded in transmitting speech 2450 feet, and this in spite of zigzags.

Macaulay, Wagner, Neef, and many more contrived at different times other admirable electric vibrators. Perhaps the most subtle and ingenious of all these however, was the one contrived by M. Duchemin a little later on, when the speaking Telephone had come to be invented, and when, to obtain vibrating plates of extreme tenuity, he employed very thin ones of mica sprinkled over with pulverised iron, which was fixed to the surface by a layer of silicate of potash. So effective was this as a means of communication, that with its help the gentlest utterance was audible; but so exquisitely fragile was the plate, that a loud voice shattered it.

Until 1876, however, articulate speech was only transmissible to a distance through india-rubber tubes and string instruments. But then at last was solved the problem of its electric transmission. Put into the fewest words the problem which then found solution was this:—To contrive some means of throwing a diaphragm into motion at a distance so as to correspond exactly with the movements of a diaphragm agitated by the voice. Do this, it was felt, and the original sounds, syllable for syllable, would, by necessity—at a distance—be instantaneously reproduced!

The time being ripe for the discovery, two electricians, as a matter of course, put in their claims all but simultaneously for the honour of having achieved it. Unknown to one another, each of them on the very same day— the 14th February, 1876—gave in at the American Patent Office an account of his invention. One of them was Graham Bell, a native of Edinburgh, but then some time naturalized as a citizen of the United States. The other was Elisha Gray of Chicago, already mentioned in these pages, and who later averred that a month previously all but one day, namely, on the 15th January, he had completed the arrangement of his system of a speaking or articulating Telephone.

However this may be, on Valentine's Day he deposited with the proper official his provisional specification. And on that same day, and in that same place, his formidable rival had put in his request for securing the rights of a precisely similar invention. Professor Graham Bell certainly had the advantage of having brought his articulating Telephone the earliest of all to the knowledge of the world in both hemispheres. It was on view that same year, 1876, at the Philadelphia Exhibition. In the September of that year at Glasgow it was spoken of by Sir William Thomson as a wonder of wonders, as a marvellous construction, and as capable of repeating, in the Morse code, four despatches at the same time. It was unquestionably the first Telephone publicly to reproduce at a distance articulate words. And it spoke so loudly that it was in no way necessary to apply the ear to the receiving instrument. When, at its introduction into this country, it was first listened to by Sir William Thomson, Hamlet's soliloquy, "To be, or not to be," was repeated to him, word for word, through the slender circular disc formed by the armature of an electro-magnet—while at the other extremity of the wire, Professor Watson in a loud and distinct voice, uttered the familiar lines in front of a tightly stretched membrane, carrying at its centre a small piece of soft iron which excited movements corresponding to the sound-vibrations of the air close to an electro-magnet introduced in the circuit. Graham Bell, in the first instance, made use, in his system, of the electric battery. For this, however, he very soon substituted a small permanent magnet of weak power, that having been found by him all sufficient. The advantage thus secured is obvious. By reducing the size and simplifying the construction of the instrument, it rendered it at once compact and portable. Another advantage it possessed was, that it was fitted both for sending and receiving, for speaking through and listening at.

From the very first it became evident both to Bell and Gray that what was absolutely indispensable for the production of speech at a distance through the articulating Telephone was the intervention of undulatory currents. Both of them indeed declared as much very distinctly on the 14th February, 1876, in their respective specifications. Each alike strove from the outset to solve the problem involved in the attempted transmission of articulate words by means of undulatory currents, obtaining those currents by the effect of induction. Graham Bell's telephones, it should be at once insisted upon, are distinctly electric, although they need no batteries. They are in no way whatever to be confused with the mere mechanically vibrating or string telephones. Electric currents, it should be remembered, are produced by two very distinct causes. There are those which are due, for example, to batteries, and there are those which are produced by the action of excited magnets on a conducting circuit properly managed. It is these latter—commonly known as induction currents—which are used in Bell's Telephones.

Graham Bell's idea as to the Speaking Telephone, it should be said at once, was realised almost at the same time, not only by Elisha Gray of Chicago, but by Paul Lacom of Copenhagen, by Cromwell Varley, and by Thomas Alva Edison. These electricians, however, by no means include among them the whole of the rival claimants to the invention. An extraordinary statement was put forth in the *Fanfulla* of Rome, on the 30th January, 1878, by Professor Farinet, which, if corroborated, would go far to show that, long before the generality of people suppose, the idea of transmitting sound to a distance had been hit upon and publicly announced. Referring to what he calls that "stupendous, wonderful, and incredible invention," the transmission of sound by the telegraph (in other words the Telephone), with the description of which he says the press of Italy had then, in 1878, been filled for some weeks, Professor Farinet goes on to remark that thirteen years previously the journals of the Roman peninsula had published accounts of a similar invention contrived by one Manzetti, a mechanic and a native of Val d'Aosta. More than this, he adds that announcements of Manzetti's discovery, which he carefully describes, by the way, to have been the transmission of articulated words by the ordinary telegraphic wire, were published, during 1865, on 10th July in the *Diritto* of Rome, on 19th August in the *Echo d'Italia* of New York, on 22nd November in the *Petit Journal* of Paris, and in many other newspapers.

The marvel of all this, however, is that for thirteen years nobody besides Professor Farinet had been at all aware of any of these blatant trumpetings of Manzetti's till then unheard-of invention. Besides this, another claimant, one John Carnock, is said simultaneously with the Italian mechanic to have invented the Telephone in 1865, though nobody knows where or under what circumstances. The like has to be stated too in regard to one Dolbear. Nor is this all. For two others are yet to be mentioned, who each preferred for himself the claim of priority as the inventor of the Telephone. One of these, by name McDonough, insisted that in 1867 he secured his rights at the American Patent Office for precisely this invention. While the other, by name Daniel Drawbough (Draw the Long Bow?) maintained that he was in possession of the affidavits of 115 respectable persons who were prepared to assert on oath that he had in actual use, to their certain knowledge, in 1870, a Speaking Telephone of his own contrivance.

Notwithstanding all this, there can be no doubt whatever that the only valid claims for rivalry on the plea of priority lie between Graham Bell, formerly of Edinburgh but now of New York, and Elisha Gray of Chicago. According to the latter these three claims of his are declared to be indisputable:—(1) That he was the first to discover the means of transmitting compound sounds and variable inflexions through a closed circuit by means of two or more elastic waves; (2) That he was the first to discover and utilise the mode of reproducing vibrations by the use of a magnet receiver constantly supplied with electric action; (3) That he was the first to construct an instrument consisting of a magnet with a circular diaphragm of magnetic substance supported by its edge at a little distance from the poles of a magnet and capable of being applied to the transmission and reception of articulate sounds. Elisha Gray, there can be no doubt of it, had from the outset all these three ideas very distinctly in his mind, as was indeed most accurately described by him in the caveat for his patent, which he accompanied even with drawings of the sender and receiver.

But, while that is so, Graham Bell was unquestionably the first who ever constructed a speaking Telephone in practical form. He was the first who ever had one of these amazing instruments publicly on view in actual working order. He was the first who ever proved to the sight and hearing of his fellow-men that the problem of transmitting articulate sounds from a distance through a common telegraph wire had been indisputably solved. On the opposite page is a representation of the simple and compact apparatus with which he proved all this to be the case in 1876, at the Philadelphia Centennial Exhibition.

Externally, both in size and general appearance, as the lower of these two woodcuts will at once show, it does really, as already remarked, resemble nothing more nearly than the handle of a child's skipping-rope. Its entire length is, in fact, no more than six inches. Examined internally, it will be apparent at once from the upper or sectional view of it here given, that it is simplicity itself in its construction. Its mouthpiece, A, serves also as an ear-piece, for the instrument can be used at option either as a receiver or as a transmitter. Its diaphragm, *c c*, is a disc of that exceedingly thin enamelled iron on which photographs are taken in batches at a very cheap rate, under the name of ferrotypes. All but touching the inner surface of this diaphragm is one end (the north pole) of the bar magnet, D, which is in fact the most

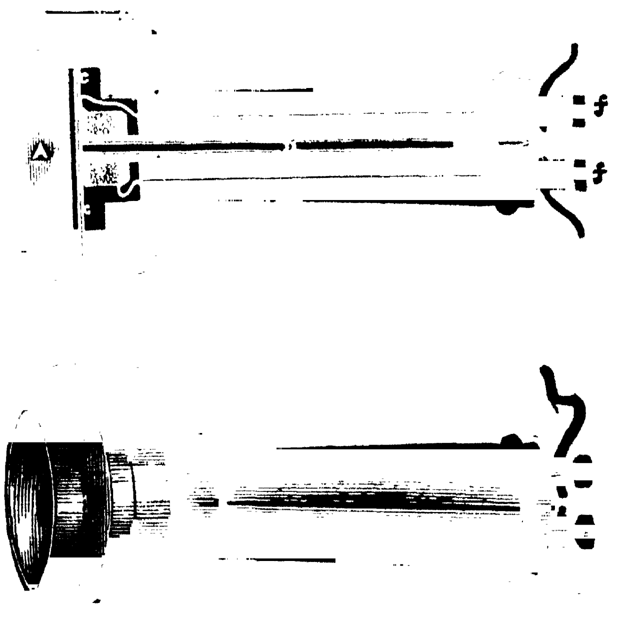

Fig. 104.—Graham Bell's Telephone.

important part of the whole apparatus. Around that north pole of the bar magnet is coiled a silk-covered copper wire, the ends of which are carried back to the smaller extremity of the wooden case, where they are connected with two binding screws, *f*, *f*, to which (to complete the circuit) the line wire and the earth wire can be readily adjusted. How the telephonic instrument may be thus joined up with the telegraphic system, the following diagram will clearly indicate—the letters *c* and *z* marking the copper and zinc elements of the battery arranged for ringing the call-bell.

Thus arranged and brought into use, the telephonic diaphragm vibrates in sympathy with the sonorous vibrations set up in it by the voice of anyone speaking into the mouthpiece. And these vibrations of the diaphragm, by constantly varying the distance between the centre of the iron disc and the magnet behind it, excite by necessity corresponding variations in the current of electricity. Transmitted thus electrically to the distant Telephone, the diaphragm there is thrown into precisely similar movements, which consequently give out, through the ear-piece, exactly the same sounds as were originally uttered into the ear of the listener.

Professor Graham Bell, on the 31st October, 1877, read a paper, descriptive of his invention, before the Society of Telegraphic Engineers. In it he explained how in one of his experiments he had fastened a piece of watch-spring about the size and shape of his thumb-nail to the diaphragm of the telephonic instrument in his lecture room at Boston University, the other end of the wire being attached, in the basement of an adjoining building, to a telephonic instrument with a precisely similar arrangement—how he had then asked through the instrument, "Do you understand what I say?" and how, to his immense delight he had received through it the immediate answer, "Yes, I understand you perfectly!" As originally displayed by him at the Philadelphia Exhibition, his telephonic receiver resembled a metallic pill-box with a flat disc as a

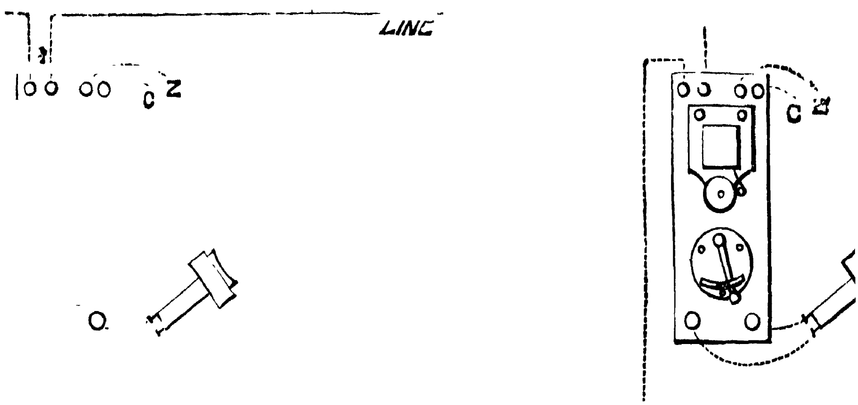

Fig 105.—Telephone joined to Telegraph

cover, fastened down at one side and tilted up at the other. One by one, however, he had introduced into his arrangement of the telephone a number of extraordinary improvements. By merely shortening the length of the coil of copper wire, he had contrived greatly to increase the loudness of the sound. By merely enlarging the iron diaphragm, which according to one of his earlier arrangements he had glued to the original membrane of gold-beater skin, he had succeeded in greatly enhancing the clearness and distinctness of the articulation. While again, by discarding the membrane of gold-beater skin altogether, and by substituting for it the thin iron plate alone, he had found that he could secure the most perfectly intelligible articulation. Finally, it was on discovering that the effects produced were equally audible when the battery was omitted, and a rod of magnetised steel introduced instead into the electric circuit, that he had decided upon employing permanent magnets instead of voltaic batteries, and in this way completing his arrangement of the Magneto-Electric Telephone.

Suggestions, more or less excellent, came from many other electricians for the improvement of the Bell Telephone. Thus, Gower's proposed replacement of the bar-magnet by one formed like the letter D, with the two poles, each furnished with a coil, brought close together, led to the substitution, for the straight rod previously used, of a powerful horse-shoe magnet.

Thus, again, Professor Jorgenson, of Copenhagen, by an ingenious modification of a Bell Telephone, contrived to impart to it an extraordinary increase of resonance. Graham Bell's own improvements of the apparatus his unassisted genius as an inventor had enabled him to construct were, however, it is almost needless to say, among all these later modifications of his original plan, by far the most remarkable. Such, for example, to give but one instance, was that modification of the Bell Telephone, which resulted from his discovery of a means for varying the intensity of the current in exact proportion to the varying inflections of sound emitted by the voice. And it should be added that this particular discovery was made by him, not as a mere spontaneous inspiration or happy thought, but as an outcome arrived at very deliberately through a long series of patient investigations in acoustic science.

To such perfection was the instrument brought at last that, scarcely breathing, you could with an undertone though inaudible to anyone two yards off, be readily heard at the other end of the line. While, if called to from the other end of the line, you could hear tne voice wherever you might happen to be in your apartment. Added to this, the clearness and purity of articulation through the instrument were irreproachable. It has been found, too, that a small copper contrivance, trumpet-like or conical in shape, when fitted on to the mouthpiece, so increases the sound that words, spoken two or three yards from it, can be readily heard at the distant station. Insomuch is this the case that when you are standing a little more than a yard from the opening of this copper horn, you can with ease hold converse with anyone at the opposite extremity of the line. At as early a date as the 12th February, 1877, Bell's telephone emitted sounds sufficiently audible to be faintly heard by a large audience in the Essex Institute, at Salem, in Massachusetts. When a short speech was shouted into a Bell Telephone at Boston, it was heard sixteen miles away at Salem by an assembly of 600 people. And upon the same occasion, but in the opposite direction, a lecture transmitted by word of mouth through the telephonic wire from Salem to Boston was published in the Boston newspapers on the following morning. At a comparatively early date in the history of the invention, a conversation was held through the telephonic wire across an interval of 250 miles, between Graham Bell, at New York, and Thomas Watson, at Boston. Later on, the Post-office electrician, Mr. Preece, announced that telephonic communication had been successfully carried on through sixty miles of sub-marine cable, between Dartmouth and Guernsey.

During the course of some experiments made by MM. Pollard and Garnier, through another sub-marine cable, connecting the Mole at Cherbourg with the Maritime Prefecture, a bugle was one day heard sounding its tantarrarara in the Prefect's study. And, upon enquiring into the cause of this, it was found that one of the manipulators had snatched up a bugle and sounded it in front of the telephone on the Mole, three miles away! Wind instruments are always very distinctly audible through the Telephone; especially from its staccato sound, the cornet à piston, which, when played in London, has been heard by thousands of people fifty miles off at Basingstoke. All that is necessary, in using an ordinary Bell Telephone, for speaking purposes, is to articulate your words very distinctly in front of the mouthpiece of the instrument which you hold in your hand—the listener at the same time holding the receiver to his ear at the distant station.

One instrument is enough at each station to render communication between any two stations complete. Two instruments, however, at each station are very much to be preferred for rapid converse—one held in one hand to the mouth, the other in the other hand to the ear, so that you can with instant alternation speak and listen. At the same time it should be said that holding one with each hand to each ear, you can hear with greatly increased distinctness. Shouting, as a rule, is of no avail. Rather than speak loudly, let your intonation be clear and your articulation syllabically accurate. With the exception of *e*, vowel sounds are the most readily transmitted. While four consonants, *g j k* and *q*, are, of all, those which are repeated by the telephone the most imperfectly. Whatever spoken sounds are transmitted should, for their better despatch, be as far as possible of musical intonation. As was proved later on, in the March of 1878, by Signor Luvini, Professor of Physics at the Military Academy of

Turin, the introduction of electro-magnets in any way inconsiderately into the circuit between two Telephones, very sensibly decreases the intensity of sound in each, the maximum of sound being produced by putting one close to the transmitting and another close to the receiving telephone. While the sounds given out by a couple of Telephones are intense in proportion to the degree of unison in their respective vibrations. The apparatus, therefore, ought in every instance to be so selected that the speaker's voice and the instrument should harmonize.

So completely an accomplished fact was the perfecting of Bell's telephone within little more than a year from its first announcement in England, that on the 14th and 15th January, 1878, it was exhibited before the Queen, at Osborne Palace, in the Isle of Wight. And on the 22nd of that month an attempt was even made (but on the whole, it must be said, unsuccessfully) to transmit, through its agency, an audible report of the Parliamentary debates from the House of Commons at Westminster to the *Daily News* office at Blackfriars. In the March of that year Mr. Spottiswoode demonstrated by experiment the surprising fact that, providing the polar extremity of the magnet were placed close to the ear of the listener, the vibrating plate of the Telephone might be actually dispensed with altogether. Similarly, about the same time, Signor Ignace

Canestrelli, Herr Wiesendanger, and others, proved that a Telephone without a diaphragm is perfectly capable of transmitting speech electrically, and this by simply magnifying the vibrations. Mr. Millar of Glasgow, in the August of that year, illustrated this in a remarkable way before the British Association, at Dublin, by means of a small bar-magnet three inches long, having a copper helix wound round it. With this in a pasteboard box, fitted above and below with two zinc plates, a song, an air whistled, the mere act of respiration at the other extremity of the telephonic wire, were shown to be distinctly audible.

All this, in fact, has served clearly to demonstrate that the transmission of speech through the Telephone arises not so much from the repetition by the membrane of the receiving Telephone (influenced by electro-magnetism) of vibrations caused by the voice on the transmitting Telephone, but is rather due to molecular vibrations caused in the whole electro-magnetic system, and especially in the magnetic core of the iron bar surrounded by the copper helix. According to this theory, therefore, it will be obvious that the vibrating plate or metallic diaphragm does nothing more after all than merely strengthen the magnetic effect of the Telephone.

Another remarkable fact in regard to the Telephone is this, that for a comparatively short distance an isolated circuit is by no means necessary. Thus, for one extending 430 yards for example, a copper wire laid on grass has been found perfectly sufficient. While even when the wire has been buried in moist earth, a Telephone has been heard simultaneously by several listeners.

Edison's Telephone, which was first announced early in 1876, almost immediately Bell and Gray had delivered in their specifications, had these two obvious disadvantages in comparison with either. First, it required a battery, and was therefore more cumbrous and complicated. Secondly, the receiving instrument and the sending instrument were different. It transmitted sound, however, very readily to a greater distance. Based like Bell's and Gray's on the action of undulatory currents, Edison's Telephone differed from both of those by interposing in the circuit semi-conducting solid bodies such as graphite and carbon, especially the carbon extracted from compressed lamp-black.

In one apparatus of his, for example, he introduced a disc of plumbago between the vibrating plate and a platinum plate in connection with a battery. In another instrument of his he placed a carbon disc of compressed lamp-black and petroleum between two platinum plates, each of the latter having attached to it a more or less elastic pad, one being made of cork, the other of caoutchouc. While a third and somewhat similar arrangement by him of the Telephone, interposed between the vibrating plate and the upper platinum plate a little iron cylinder instead of the caoutchouc pad, the mouthpiece of the instrument being larger and more prominent, the instrument itself

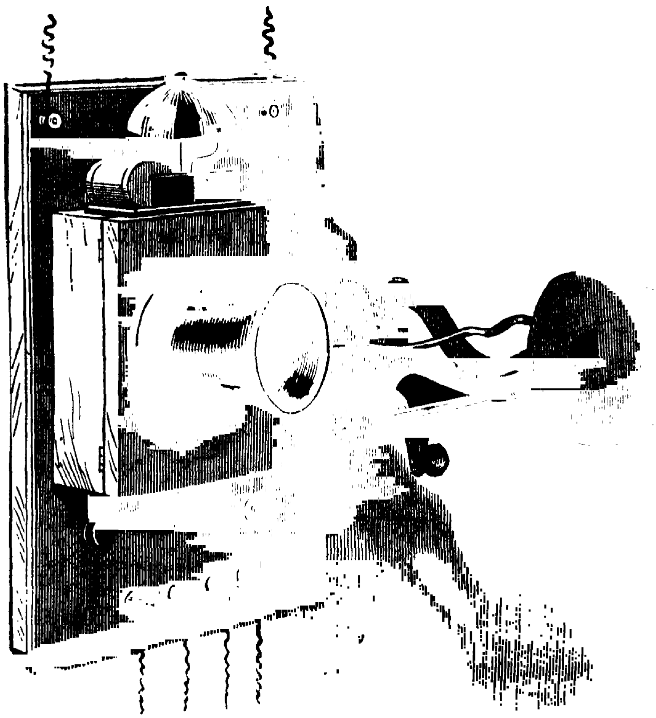

Fig. 106.—Exterior of Edison's Loud-Speaking Telephone.

being encased in nickel silver, and the rigid disc on the top of the lower or inner platinum plate being not ebonite but aluminium. Edison's Carbon Telephone was tested with the happiest results, on the 2nd April 1878, through the 106 miles of wire connecting New York and Philadelphia. With a small induction coil and a battery of only two cells he was enabled thereby to converse, with the greatest ease, at that distance, with Messrs. Phelps and Batchelor.

An improvement on Edison's one carbon disc was very soon suggested, however, by Colonel Navez—to wit, the employment of several. By the interposition of the carbon disc, all that was aimed at, from the outset, by Edison, was the modification of the resistance of the circuit. In that direction, even when used singly, its action was most effective. Its multiplication, thus, therefore, was not unreasonably proposed.

Edison's most memorable achievement of all as a telephonic inventor, however, was in the production of his loud speaking, or as it is sometimes called with good reason, his Shouting Telephone. If merely regarded in its compound character, it is certainly remarkable, for its action is threefold, that is at once electrical, chemical and mechanical. It was for a long time one of the chief marvels on view at the Polytechnic Institution. There Professor Pepper lectured upon it, day after day, for months, to the delight and wonder of large audiences. His assistant on these occasions, instead of being as usual present there in the lecture-room, was at a considerable distance from him, at a house in Cavendish Square—the sole means of communication between them being a fine copper wire. Seen from without on the platform by the side of the lecturer, the little apparatus appeared as on a preceding page. Through the mouthpiece of it, at intervals, the assistant at the other end of the wire at the house in Cavendish Square, sang a song, or played a solo on the cornet à piston to the accompaniment of a piano in the lecture-hall. Examined internally, this was the simple arrangement of the contrivance :—

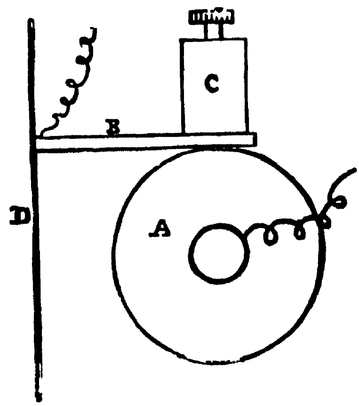

Fig. 107.—Diagram shewing the action of the Shouting Telephone.

A cylinder of chalk A, moulded upon a metallic roller, has a handle attached to it, which projects outside the instrument, and by turning which the cylinder is rotated. The substance of the chalk, however, it should be said, has been previously impregnated with caustic potash. Pressing upon the upper surface of the cylinder is a horizontal arm or bar B, faced with platinum and weighted above by an india-rubber pad C. This arm is fastened to the centre of a four-inch diaphragm of mica D. Whenever the cylinder revolves the friction generated between the arm B and the surface of the chalk cylinder A, causes such a pull upon the mica diaphragm D, that it assumes a form slightly concave. Directly the electric current, however, is caused to pass between the cylinder A and the arm B, all friction instantaneously ceasing, gives place to a wonderful slippery gliding of the chalk cylinder under the platinum, as though either or both of them had a surface of ice—the diaphragm D, as a consequence of this, instantaneously springing back to its original perpendicular position.

This mysterious slipping or gliding effect is simply the result of the action of the electric current upon the caustic potash with which the chalk has been previously impregnated. But whether arising from the fact that minute bubbles of gas have in consequence been given out which may thus form so many cushions of vapour for the platinum to glide along, or whether from the salt of the potash in infinitesimal quantities being reduced to the metallic state, thus causing all friction to cease, still remains a moot question. However this may be, the arrangement in this way made, is so wonderfully sensitive to minute variations of friction that the alterations of the force of the magneto-electric current, caused by a voice speaking in front of a carbon transmitter, are immediately translated into corresponding variations of friction, the mica diaphragm thereupon vibrating sympathetically to every such subtle variation, and the original sounds being thus sonorously reproduced.

Besides the three great systems of telephonic communication already described, those of Graham Bell, of Elisha Gray, and of Thomas Alva Edison, many others have competed with one another for public approval. Among these rival systems, those of Trousé, of Demoget, and of Mac Tighe may cursorily be specified. One particular instrument, contrived by M. Righi, for a time attracted great attention at the Académies des Sciences et des Arts et Métiers, as well as at the Press Pavilion of the Electric Exhibition at Paris in 1881. This, which was audible simultaneously to a large assembly, was in fact a huge Bell Telephone, having a diaphragm of parchment, with a sheet-iron disc at its centre. A composite kind of Telephone, contrived by Gray and Phelps, was remarkable for this, that the intensity of its sound was in proportion to the number of its diaphragms. One, designed by Cox Walker of New York, was noteworthy as having no less than eight diaphragms. Still more satisfactory results than those thus arrived at, have been attained by having two or even four Telephones, placed side by side, linked together by horse-shoe magnets. Phelps's telephonic system, in point of fact, renders it possible to hear the words articulated, from no matter what distance, as though the person were speaking in a loud voice in the same apartment. In appearance, his apparatus, which is oblong in form, somewhat resembles the well-known scientific toy, the gyroscope. In its intonation, moreover, it has this advantage, that it is entirely free from that punch-and-judy voice so frequently noticeable in other Telephones. Phelps's latest contrivance, popularly known as the Crown Telephone, now widely in use in the United States, is combined with Edison's carbon sender. In it the two systems are worked by six horse-shoe magnets radiating round the magnetic core. And the magnetic field being thus considerably enlarged, the articulated sounds are very much intensified.

A liquid medium, introduced into the circuit, has been tried with no less happy results than a dry one, by various experimentalists. Professor Bell, for example, constructed an admirable receiver by attaching to a stretched membrane a platinum wire, which completed the voltaic circuit by dipping into water; though louder sounds still were produced when, in lieu of water, there was employed dilute sulphuric acid or saturated solution of salt. M. Richemond, again, with a view to a slight modification of the resistance of the circuit, employed water in his Electro-Hydro-Telephone.

With excellent effect, moreover, in what are known as the Mercury Telephones, pencils of it attached to two vibrating plates have been dipped through acidulated water into a substratum or sediment of quicksilver. MM. Pollard and Garnier, it should be added, employed, with good results, under a vibrating tin plate, a couple of graphite points with their porte-crayons. While, on the 3rd May, 1878, M. Hellesen, in his re-action Telephone, with yet better effect attached a lead pencil to an iron vibrating plate—Elihu Thomson and Edwin Houston, less than two months later, announcing that, in their rival re-action system, by somewhat similar means, the sound of the voice was much less altered than in any other Telephones.

What is especially remarkable in regard to this wonderful invention of the Telephone, by whomsoever the apparatus may have been constructed, or upon whatsoever system, is this, that it is incomparably the most sensitive of all instruments for revealing the action of electric currents.

Until M. d'Arsonval's experiments had demonstrated this beyond the possibility of further denial, the nerve of a frog had been regarded as the most perfect of all known galvanoscopes. Thenceforth, however, it has been demonstrable at pleasure that the sensitiveness of the Telephone, which is indeed exquisite, is absolutely 200 times greater than that of the frog's nerve.

As early in the history of the discovery as in the summer of 1878 the Telephone Company was first incorporated. A twelvemonth afterwards, in 1879, the Count du Moncel had assumed his place by right as its earliest historian. Since then the telephonic system has spread with wonderful rapidity in this country, in various parts of Europe, and on both sides of the Atlantic.

How admirably it can be worked at any great central station was first shewn in London, at 11, Victoria Street, by Edison's Telephone Company. There, in a spacious public-room, opposite a huge switch-board, sat a clerk who was as the spider at the centre of a huge web of wires spun to all parts of the metropolis. On the switch-board, a number of little discs were displayed. An electric bell rings, and simultaneously one of these little discs drops, revealing in its place "No. 12." Thereupon, the clerk, switching his telephone on to that number, asks what he (No. 12) wants? The answer comes immediately, "Put me on to number 27." Upon this, by merely moving a small metal peg into a particular hole on the switch board, the clerk at once puts 12 and 27 into communication. A simple movement of this kind has thus brought instantaneously into easy talking distance of each other, just as if they were face to face in the same room, let us say, for example, a merchant in his West-end villa and his confidential manager at his city office—what they may have to say to one another (each in his private room) being absolutely inaudible at the central station.

When their conversation is finished, again the electric bell rings, and their numbers drop, as a signal that they have done talking. For 12*l.* a year the advantage of the exchange system, in this way, could be secured. But for 19*l.* a year a special wire could be monopolised. What used to be done thus, however, by a company, is now done exclusively in this country, as the transmission of our letters and telegrams had previously been, by the Government.

So completely had the system got into working order in the north of Europe, at as early a date as the 1st October, 1881, that in Berlin 533 houses were, even then, served with telephonic communication, the total length of telephonic wires in that capital down to that date being 750 miles.

Before the spring of 1883, the greatest single length of wire ever traversed audibly by interchanging voices through the Telephone, had been along the 700 miles separating New York from Cleveland. Then it was, however, as already mentioned in the opening sentence of this record, that, on the 25th March, 1883, audible converse was held through the 1000 miles of telephonic wire connecting the Empire City of the United States with Chicago. That achievement, it should be said, was mainly due to a novelty in the conductor, which consisted of a steel wire core, copper plated, the electric resistance of which, across that interval of 1000 miles, was no more than 1522 ohms as against the 15,000 ohms representing the average resistance of the ordinary iron telephonic wire, thereby, in other words, reducing by one-tenth the whole force of the electric resistance.

So memorable a feat, it must be obvious at once, indicated, from that moment, the dawn of a new era in the development of telephonic intercourse. Thenceforth, knowing as we now do, as an actual and accomplished fact, that the voice can be heard instantaneously through the material medium of a metallic wire across an interval of 1000 miles, it must be manifest that, with the same agencies duly applied, any distance, not merely 1000 miles, but absolutely any distance, may, by the voice, in the same way and with the like ease, be instantaneously traversed. So far as this globe is concerned, the time may be reasonably looked forward to when, not only the telegraphic wire, but the telephonic wire may put a girdle round it more rapidly than that promised by Shakspeare's tricksy sprite, and when men at the opposite ends of the earth may very literally be within speaking distance of each other, though separated at the moment by actually half its circumference.

The merest accident—the snapping of a fine wire during the course of an experiment—led to the discovery by Professor Hughes, of that marvellous magnifier of minute sounds, the Microphone.

Fully aware that the Magnetic Telephone was an instrument absolutely complete in itself, or in other words that it needed no aid whatever from the electric battery, he, nevertheless, thought that, purely as an experiment, he would put it in circuit with a weak battery-current, and see what might then happen. How intimately connected magnetic and electric action are, Professor Faraday had, years before that, resplendently demonstrated. With everything that great electrician had thus brought to light, Professor Hughes was, of course, perfectly familiar. When entering upon his own investigations, therefore, in a field so often previously trodden by Faraday, he was conscious that he was merely walking in his predecessor's footsteps, but he knew equally well, at the same moment, that he was doing so with the help of an apparatus undreamt of even in Faraday's philosophy.

At the outset of this independent enquiry of his own, Professor Hughes included in the electric circuit with the Magnetic Telephone, a battery of weak power, doing this with a very fine wire to which he attached weights, one by one, until, by their accumulated strain upon it, the wire at last should be compelled to snap. Having made this arrangement, while vigilantly listening at the ear-piece of the Telephone, he noticed, upon adding what proved to be the last weight necessary, that immediately before the wire broke, a peculiar kind of rushing sound was audible. Thereupon, in a seemingly idle mood, he loosely twisted or linked the broken ends of the wire together so that the electric current could still pass freely. Then it was that Professor Hughes discovered to his amazement that, by this exceedingly simple device, he had, in a wholly unpremeditated way, contrived haphazard an exquisitely sensitive detector and expander of sounds that would otherwise have remained inaudible. Every minutest noise near the loosely joined wires, he then observed, in fact, was given out not only appreciably but as a loud sound by the connected Telephone.

Having taken note of this surprising fact, he slightly modified his arrangement by placing three nails, lightly touching one another in circuit, after the manner shown in the following woodcut.

The result of his experiment in that instance proved equally efficacious. He next tried what the effect would be upon loosely fitting the upper and lower ends of a small double-pointed pencil of carbon between two small hollows in a couple of carbon blocks, in the way indicated by the subjoined section of the Carbon Microphone.

The result of this arrangement proved to be something really wonderful. For, he then found that, upon depositing this little contrivance, with its lightly held carbon pencil, in a room in which ordinary conversation was being carried on, he could, in a distant apartment, several streets off, hear very distinctly the words uttered by the different speakers by means of an ordinary telephonic wire placed in circuit with an electric battery.

Marvellous in its effects though the Microphone is, so

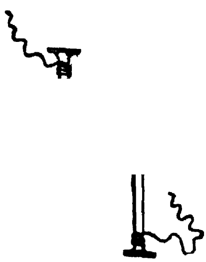

Fig. 108.—The Nail Microphone.

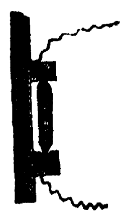

Fig. 109.—Section of the Carbon Microphone.

far is it from being either costly or complicated that, as already intimated, the first one constructed by its inventor was built up with such trivial materials as a match-box and a penholder, in combination with a little sealing-wax, wire and string, while his electric battery consisted of nothing better than three small pickle bottles, each filled up, like the gallipot represented overleaf, as a Microphone Battery Cell.

There, coiled up, snake-like, at the bottom of the jar, is a copper wire the end of which projects upwards and outwards over the rim—the straight part of this wire, where it passes up the inside of the jar towards the surface, being, for the purpose of insulation, coated with either sealing wax or gutta-percha. Upon the coil of wire at the bottom of the vessel is then poured about half-an-inch of water. Immersed in this water are two ounces of sulphate of copper, C, otherwise bluestone, broken into small lumps each about the size of a pea. Its contents having been thus arranged, the jar is then

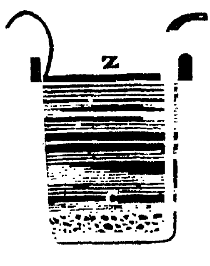

Fig. 110.- A Microphone Battery Cell.

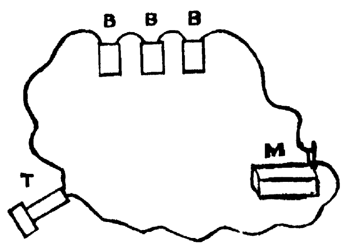

Fig. 111 —Microphone in circuit with Battery and Telephone.

all but filled up with either moist clay or damp saw-dust, upon the surface of which is placed a disc of zinc, Z, from the edge of which (exactly opposite the end of the copper wire) protrudes a little band or half curl, resembling in shape the tongue of a jew's-harp. With three small battery cells like this, Professor Hughes found that a Microphone can at all times be worked effectively.

How readily the component parts of this triple arrangement—the Microphone, the Battery, and the Telephone—can be joined together in circuit will be best shown by the above diagram.

So small need the carbon portion of the Microphone be that it will be amply sufficient if it is an inch in length. It is most frequently mounted, and always with good effect, on a vulcanite or ebonite plate as below.

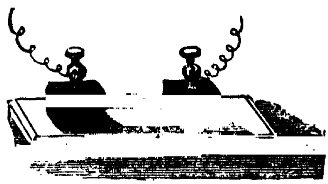

Fig. 112.—Microphone on Ebonite Plate.

In this position, binding screws are affixed to the carbon blocks, so as to admit of the apparatus being easily brought into circuit by attachment to the wires. A better arrangement still is to fasten the instrument to a sounding box, as is shown in the annexed outline.

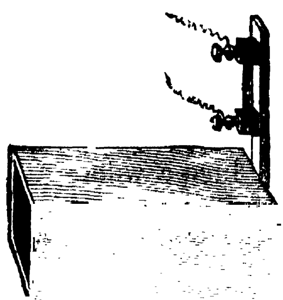

Fig. 113.—Microphone on Sounding Box.

By so treating it, the resonance of this little wonder-working contrivance is very considerably increased.

More sensitive, perhaps, than any other arrangement of the Microphone yet particularized, however, is one in which a small bar of carbon is so delicately balanced on a brass pivot that one end of it lightly touches a fixed block of the same material. For the convenience of the experimentalist, the framework or stand upon which this nicely adjusted apparatus is fixed—as a glance at the subjoined woodcut will show—is prolonged.

A watch placed upon this prolongation of the stand will yield extraordinarily loud results, not only by the magnifying of the pulse of its balance-wheel, but by the

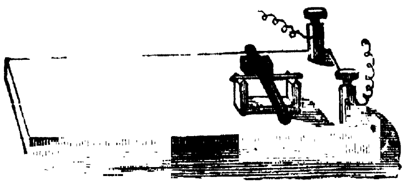

Fig 114 —Horizontal Bar Microphone.

rendering audible besides of many other sounds in its intricate mechanism. The mere writing, there, with a quill pen, will with the every movement of the nib along the paper, produce a wonderful resonance. Nay, the slightest touch of a feather on the carbon, which would be quite inaudible to the unassisted ear, causes a loud noise.

As remarkable an experiment as any that can be made, however, to test the efficiency of the Microphone, is to imprison a fly, a gnat, a moth, or any other small insect in a common match-box, over a hole previously cut in one side of which a piece of muslin or a sheet of straw-paper has been stretched. Upon placing the box so arranged upon the stand of the Microphone, you will not only at once hear the otherwise inaudible tread of the fly, but you will hear it tramping about as though it were a horse or a bullock. Piercingly distinguishable, even, is the dying scream of a fly through the wonderful agency of this little instrument.

It does by the sense of hearing, in fact, precisely what the microscope does by the sense of sight—it magnifies what without its help would be absolutely indistinguishable. So powerful is its agency, as an outcome or adjunct of the Telephone, that one form of the Microphone has been contrived by M. Boudet de Paris with the aid of which a small Telephone is enabled to utter a very loud sound.

Two adaptations of the microphonic principle have come signally to the assistance, one of them of the surgeon, the other of the physician. With the help of the Sphygmophone, for example, the latter can readily hear all over a room the sound of his patient's pulse. While, with the help of the Audiometer, the aurist can test, at will, with absolute certainty, the progress of his patient's improvement.

A greater marvel than the Microphone, however, has yet to be described as the most weird of all the emanations of the Magnetic Telephone. This is that little portable apparatus of the Phonograph which is, everything considered, perhaps the most wonderful of all the three hundred scientific achievements of its inventor, Thomas Alva Edison. For, more distinctly than any of them, it has given him something really like a reasonable claim to the title he has long enjoyed as the Wizard of Menlo Park. Nor can this assertion be regarded as in any way extravagant when it is added that, with his contrivance of the Phonograph, he has enabled a vibrating metal disc, a steel point, and a revolving brass cylinder, to speak as articulately as the lips of a human being.

Léon Scott's Phonautograph, already described, had, long prior to the invention of the Telephone, enabled experimentalists to obtain an exact (visible) record of sounds. Edison's marvellous discovery of the Phonograph did far more than that, however. It not only took exact record of sounds with the indentations of a steel point instead of with the blurred touches of a feather, but—going far beyond this—it actually repeated those sounds aloud and articulately.

Before the January of 1877 had closed, Edison had patented his invention of the Phonograph. But it was not until the 31st July of that year that he had indicated outside the patent office the principle upon which it was constructed. He did so by announcing that it was a system of registering spoken words by means of indentations traced with a stylus upon a sheet of paper wound round a cylinder, this cylinder having a spiral groove cut on its surface. Indented tracings thus made, he further intimated, were then employed for the automatic transmission of the same clearly articulated message by passing them again under the stylus, which would thereupon react upon a current breaker after the manner of Wheatstone's rhéotome.

Intermediately between the two dates last mentioned, as so often happens in regard to any entirely new discovery, another experimentalist in a different part of the world, M. Charles Cros, of Paris, on the 30th April, 1877, deposited, in a sealed paper at the Académie des Sciences, a statement in which he pointed out the principle of an instrument whereby speech might be articulately reproduced.

One memorable day, in the December of 1877, however, the young American inventor whose patent for the Phonograph had been secured nearly a year previously, gave practical evidence in an astounding way that he had actually solved the problem which the French dreamer had only theoretically propounded. Edison did so by walking into the office of a well-known journal in New York, the *Scientific American*, and placing with his hands upon the editor's table, a compact little instrument of his own construction, now familiar to the whole world as Edison's First Phonograph, represented in Fig. 115, overleaf. There and then, on the inventor merely turning the handle, D, of this small piece of mechanism, the machine itself asked quite articulately, from its central mouthpiece, F, "How is your health?" and, again, "How do you like the phonograph?" It further announced, "I am very well!" and finally, "I bid you a hearty good night!"—the words

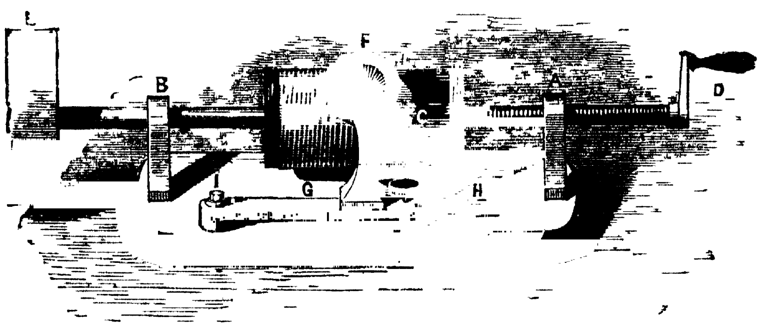

Fig. 115.—Edison's First Phonograph

thus coming from the apparatus being perfectly audible to the more than dozen people who were there assembled. On the 22nd December, 1877, a full account of this extraordinary incident was published in the *Scientific American,* this report being copied verbatim into the London newspapers in the January of 1878

How that original Phonograph acted admits, now, of easy explanation. Across the inner orifice of the mouthpiece, F, was stretched a thin mica diaphragm, bearing at the centre of it, at the back, a small steel point. Placed immediately behind this was a brass cylinder, C, supported on a shaft which was screw-threaded. At one extremity of the shaft was the crank, D, the mere turning of the handle of which caused the cylinder, while it revolved, to have a horizontal movement as well at the rear of the diaphragm. At the other extremity of the shaft was the heavy flywheel, E, which was introduced simply for the purpose of steadying as far as possible the equable motion of the cylinder. The instrument's base-board, G, had at its opposite ends, A, and B, the bearings on which the screw-threaded shaft turned. For exactly adjusting the position of the mouth-piece, relatively to the cylinder at its back, the lever, H, was employed, I marking the place of the nut on which it worked. Seeing that the cylinder, while it revolved, had simultaneously, as we have said, a horizontal movement, it will be obvious that the steel point during the double motion described on its surface a spiral trace. To correspond precisely with this, immediately behind the steel point, a spiral groove was cut in the brass cylinder. While, before bringing the apparatus of the Phonograph into operation, there was always wrapped round the cylinder a sheet of tinfoil.

These being the arrangements of the instrument, whenever any words were uttered in front of the mouthpiece (the handle of the machine, of course, being at the same time turned), the diaphragm vibrated sensitively to every modulation of the voice. Exactly in accordance with these vibrations the steel point at the centre of the back of the diaphragm indented the tinfoil where the latter crossed the spiral groove on the brass cylinder. These indentations were by necessity the exactest conceivable record of the varying sounds of whatever words had been uttered. And with the material record of the sounds thus secured by the Phonograph, Edison completed the marvel of his invention by enabling the machine itself to reproduce articulately, syllable after syllable, whatsoever human lips had previously spoken in front of the mouthpiece.

Before explaining how this most wonderful action of all on the part of the Phonograph was accomplished, it may be as well for the reader to obtain a yet keener insight into the inner part of its mechanism, as he may by examining the engraving opposite, which gives a sort of profile view of it, or in other words, a Section of the Phonograph.

It will be recognised at once upon the merest glance at this drawing that D is the crank, C the cylinder, BB and G the frame-work and stem of the mouthpiece, H the lever for its adjustment, A the diaphragm, S the adjustment screw, E the spring support to hold the stylus rigidly in position, and P the steel point, immediately between which and the diaphragm will be observed two pieces of india-rubber tubing, which were there introduced so as to muffle or deaden, as with a couple of tiny cushions, the sound that would otherwise have been too metallic in its general character.

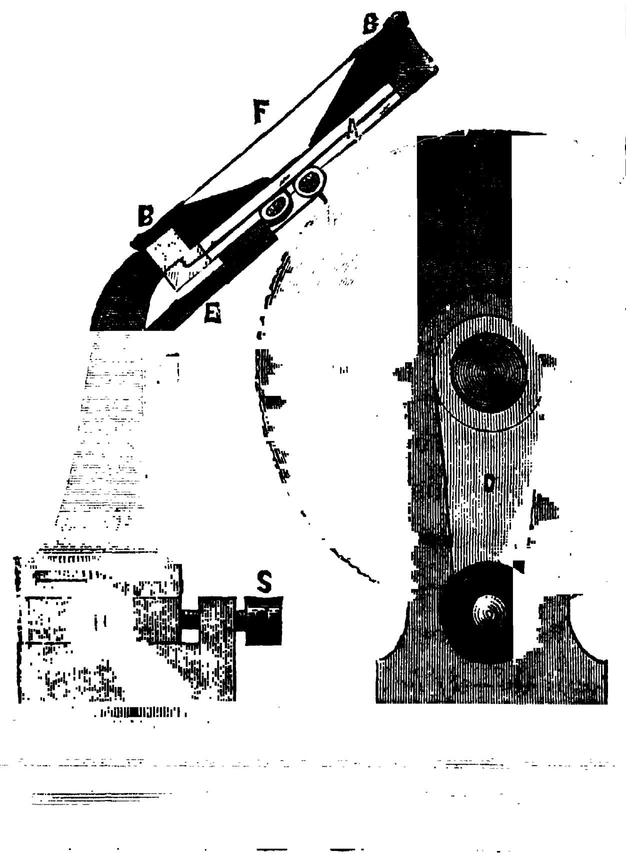

Fig. 116.—A Section of the Phonograph.

Having, with these appliances and in the way already described, obtained a perfect record of whatever words had been spoken into the mouthpiece at the same time that the handle of the instrument had been turned, the shaft of the cylinder was pushed back into its original position, and the crank being thereupon again set in motion, the apparatus once more travelled over the very same ground it had already traversed. In so doing, the tiny steel point on the centre of the diaphragm again found its way, one after another, into every minute indentation marked in the spiral groove on the tinfoil wrapped round the cylinder. And as it, thus, as it were on tiptoe, stepped in and out of its own footprints, the diaphragm, to which it was attached, vibrating responsively, gave out identically the same sounds that had originally been uttered.

It was while the great American inventor was putting together with his own hands, in his workshop at Menlo Park, the first experimental machine for the recording of sound, that—it suddenly occurred to him—*If* the thing he was forming would do what he was trying to make it do—*If he spoke to it, it ought to speak back again!* Hurriedly giving the last touch or two to the apparatus he was at the moment manipulating, he, immediately after this startling thought had flashed through his mind, put it, there and then, to the test!

Turning the handle of the machine, he spoke into it, very quietly but with the clearest articulation, these words—"Mary had a little lamb; its fleece was white as snow." What followed, Edison, on the morrow of his discovery, related with his own lips to the trustiest friend he has in the world, Colonel Gouraud, who, ten years previously, may be said to have, himself, discovered the young inventor.

Looking about him in his immense laboratory, after shifting the cylinder of his little machine back to its original position, Edison saw standing there, the least removed from him of all his many assistants, a German workman named Fritz. Calling the latter to him—and pointing to a particular part of the machine—he told Fritz to put his ear down there! Fritz, having no notion of what this direction meant, put his ear down. The sequel shall be related in Colonel Gouraud's (or rather, as will be seen, in the Inventor's) own words—"Edison started the machine in motion, and he said to me, 'I watched that Dutchman's face; it was a curious thing to observe the changes of expression that came over him. Finally, he straightened himself up, raised his hands in the air, and said—*Mein Gott, she speaks!*'"

Until the public announcement, in the December of 1877, of his astounding discovery of the Phonograph, Edison's name may be said to have been in a great measure unknown except to his own immediate surroundings. Upon the morrow of the day, however, upon which that almost incredible achievement was brought to the knowledge of the world, it was bruited abroad with magnetic celerity all over the globe. For, as his earliest appreciator has expressed it, "Every telegraph wire flashed the fact under sea and across continents, and it was the theme of discussion, discourse, amazement, and delight in every language."

Not long after this, besides, his earliest fame as the inventor of the Phonograph, was accentuated in a remarkable way by his extraordinary contrivance of the Carbon Transmitter which has thenceforth been an essential and indispensable adjunct of the mechanism at the sending end of the Telephone.

An interval of fully ten years elapsed, however, after Edison's fabrication of his First Phonograph, during which he apparently gave no further thought whatever to the improvement or development of that most surprising invention. His attention in fact was drawn aside during that long interval, and all but monopolised, by his strenuous, and at last triumphant, endeavours to bring the Electric Light within reach of all, by securing its subdivision in hermetically sealed glass bulbs with the aid of his delicate carbon filament.

Nevertheless, all that while, his thoughts frequently reverted at odd moments to the contrivance which had first rendered him, in the most literal meaning of the phrase, world-famous. Engrossed through a whole decade, though he was, by his labours in connection with the Electric Light and the Telephone—with the perfecting of both of which great inventions his name must henceforth, in consequence, be pre-eminently associated—it was inevitable, indeed, that his glance must often have been turned wistfully askance in the direction of his too long neglected Phonograph.

At length, both the other inventions having been swung into a brilliant success—the one mainly by the Carbon Filament, the other mainly by the Carbon Transmitter—the contriver of the first sound-recording machine the world has ever known, had leisure at last to reconsider, and bit by bit to readjust and, as far as possible, perfect, that wonderful little instrument.

Edison's earliest Phonograph having been announced, as will be remembered, at the fag end of 1877, nearly eleven years, it will be seen, had run out when, in the Autumn of 1888, his Latest Phonograph, was, not only announced, as having been completed, but was brought over to the mother country and publicly exhibited, on the 14th August at Norwood, by the inventor's friend and representative in England, Colonel Gouraud. On the 6th of the following month, it was displayed by him at Bath before the British Association. Later yet, on the 28th of November last, he submitted it to the consideration of the Society of Arts, and, latest of all, on the 19th June 1889, placed it, as the last miracle wrought by mechanical science, before the Royal Society on the occasion of their most recent conversazione.

Wonderful though Edison's Phonograph of 1877 undoubtedly was in itself, it has been so immensely improved upon by its successor, that it cannot be mentioned in the same breath with Edison's Phonograph of 1888. Each is based, of course, on the same fundamental principles. But the appliances brought together in the old machine will be seen to have been but rude and primitive, when contrasted with those forming the constituent portions of what we are fain to call the present perfected masterpiece.

Instead of weighing, as the first comparatively clumsy machine did, over 100 lbs., the present beautifully compact little instrument weighs no more than 34 lbs. altogether.

Instead of the indentations constituting its record being made by the stylus, as formerly, upon a sheet of tinfoil wrapped round the spirally grooved drum traversing on a screw, they are made upon a small and shapely cylinder of paper, covered over by a film of wax, or of some other waxlike composition.

Instead of the movements of the whole of this delicate little piece of mechanism being caused by the rude device of turning a handle, the machine is set in rotation either by foot propulsion, or by the agency of a silent Electric Motor, hid away in the hollow wooden base on which the instrument is fixed as upon a pedestal.

Instead of a single diaphragm, and that of mica, being employed as formerly, both for recording and for repeating, two diaphragms of entirely different materials, one rigid, the other flexile, are employed alternately—one of *glass* for receiving and recording the vibrations—one of *silk* for repeating or re-articulating them.

As at present constituted the Phonograph, in its now completed form, has a small horizontal steel shaft traversing on a screw, and having at one end of it a tapered brass mandrel, on to which a wax cylinder, in its turn slightly tapering inside, is fitted. This wax or wax-like cylinder, called in its untouched or virginal state a "phonogram blank," becomes when once it has been indented by a recording stylus what is then technically termed a "phonogram." The thickness of the wax upon these phonograms varies, it should be said, according to the purposes to which they are applied. If intended to be sent by post, or employed for a single message, they are very thin indeed. While others, designed for general use, and for a greater amount of wear and tear, admit on the contrary of being increased to considerable thickness, some having as many as ten, or thirty, or even 400 surfaces and upwards, any one of which, when the record has served its purpose, can be planed off the surface by a cutting tool attached to the underside of the plate carrying the diaphragm, which tool always precedes the recording stylus for the purpose of trimming up or smoothing the wax surface in front of it.

Merely waxen though the record be, what is yet more remarkable about it, is the fact, which experience has proved, that it is capable, without any detriment of giving off, as clearly and articulately as at the first, almost any number of repetitions. This, although the spiral actuated by the guiding screw (being just $\frac{1}{100}$th of an inch in width) is scarcely visible to the naked eye, while the record indented at the bottom of the track is so exquisitely minute that it can only be dimly seen with the aid of a very strong magnifying glass. Yet, whatever sound goes into the instrument is so surely put upon record there, when once the needle is dropped into contact with the phonogram—a fact indicated to the manipulator by the faintest *hissing sound*—that if you hum and haw, if you blurt out a momentary expletive, or evidence your impatience in any other way, by stamping your foot, or banging your fist upon the table, or slamming the door, it is all pitilessly jotted down by that inexorable recorder. Insomuch that it is agreeable to see, from the illustration on the opposite page, how ingeniously the inventor of the Phonograph has enabled anyone speaking into it, to evade any difficulty of the kind, by attaching to the machine something like an ordinary piano pedal—by pressing his foot on which, at any moment he can, whenever he pleases, lift the needle away from the revolving wax cylinder

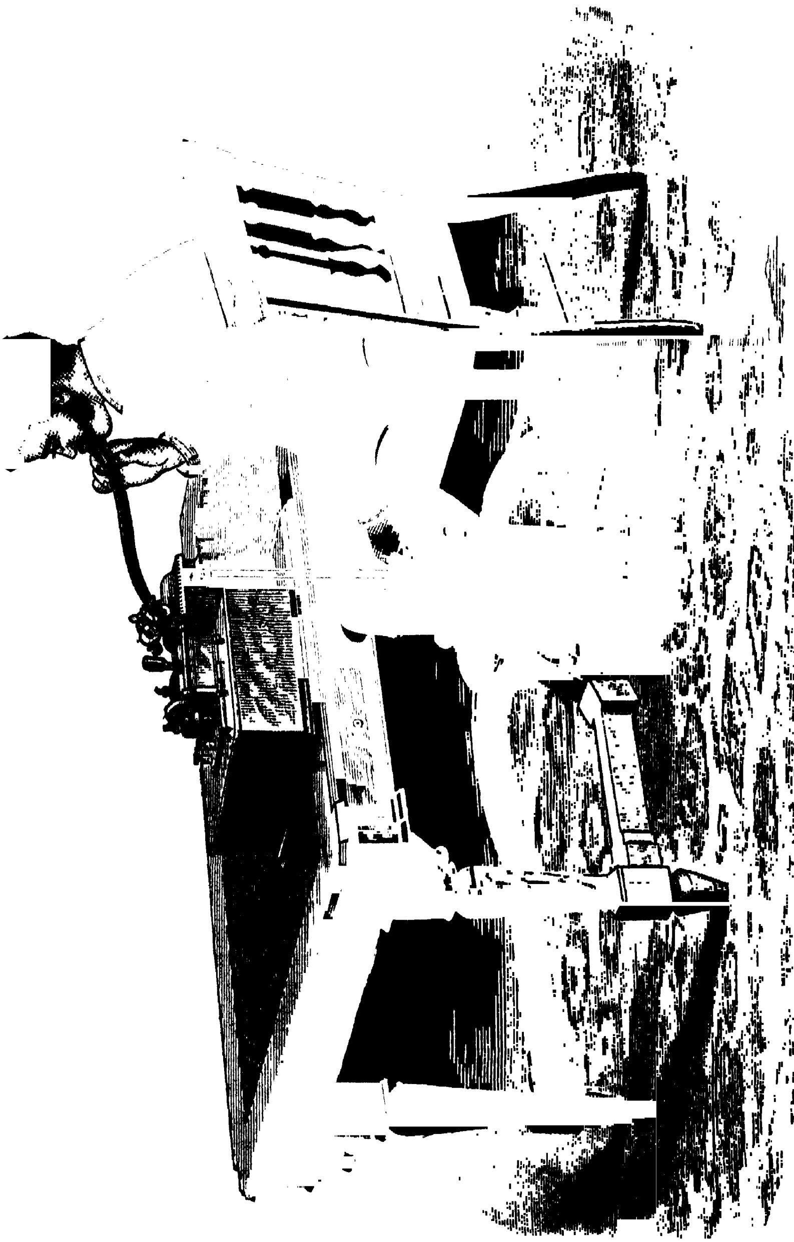

Fig 117 —Contact between Needle and Phonogram regulated by a Pedal.

Seeing that Edison had made clear to the whole world as many as eleven years ago, that a sound-recording, and a sound-reproducing machine, utterly impracticable though the idea of anything of the kind had hitherto seemed to have been, might be very readily constructed, it could hardly be matter for surprise that when, at the end of a whole decade, he reappeared with his present perfected Phonograph, he should find himself confronted by other inventors, who had caught up the suggestions thrown out by him in 1877, and after their own fashion, had now very newly and cleverly applied them. Anyhow, such, in point of fact, proved to be the case, when Professor Graham Bell, Dr. Chadwick Bell, and Mr. Charles Sumner Tainter of Washington—all of whom had previously competed with Mr. Edison in other scientific researches—brought out almost simultaneously with his perfecting of his ten-year-old Phonograph, a contrivance of their own, which, from the very title they have given it, seems like an inverted reflection of Edison's Phonograph, seeing that, by merely transposing the two Greek words lying at the root of each, they have dubbed theirs the Bell-Tainter Graphophone.

A glance at the accompanying illustration will enable anyone to realise upon the instant its general character and appearance. Mounted upon a table provided with a hinged lid which can be shut down and locked when the instrument is not in use, the Graphophone, which has also underneath it a balanced treadle and driving wheel, has in its general contour a certain resemblance

Fig. 118.—The Graphophone.
A. Diaphragm Frame; B. Speaking mouthpiece; C. Repeating Style and Bifurcated Ear-tubes; D. Wax Cylinder; E. Pedal and Balanced Treadle.

to some of the ordinary Sewing Machines. If in its general arrangement it hardly seems to justify the sanguine expectations indulged in, as to its proximate success, by the ingenious triumvirate who have called it into existence, it would be idle to deny it the merits of extraordinary ingenuity and scarcely less extraordinary simplicity. A greatly magnified sectional view of the cutting style making its record on the wax-covered paper cylinder of the Graphophone, ripping up a waxen shaving before it as it advances, will afford a suggestive peep also into its interior operations, and by so doing will illustrate yet further the abounding ingenuity lavished upon its every detail by its three able inventors.

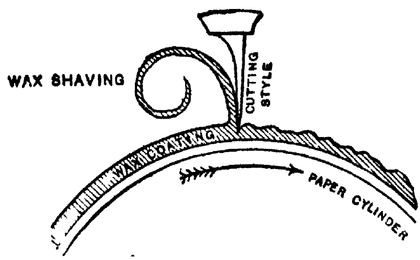

Fig. 119.—Cutting Style on the Wax Cylinder of the Graphophone.

Reverting, however, to Edison's Phonograph in its new and perfected form, it should be said at once that the two diaphragms now employed alternately—the rigid glass one for recording, and the ductile silk one for repeating—are fixed, side by side, in a plate, jointed on to the back frame of the machine, which plate is called the Spectacle, from its great resemblance to a pair of glasses.

By merely shifting this moveable plate of the

Spectacle, to right or left through some ninety degrees, you bring, at option, either the one diaphragm or the other into acting position immediately over the wax cylinder. And the vibrations wakened in each diaphragm by the sound waves passing in through the mouthpiece to be recorded on the phonogram, or passing out from the instrument when its record is being repeated, vary in their number, when musical from forty to nearly five thousand, and when beyond the limit of what is termed music to upwards of forty thousand.

Whatever their number may be, whether musical or otherwise, they are one and all recorded by the puncturing needle, or repeated afterwards at pleasure with unfaltering accuracy by the slightly blunter stylus trailed over the almost infinitely minute indentations.

Every imaginable sound that goes into the machine, when it is given forth again is most faithfully reproduced. Nothing is beyond the reach of its all embracing capacity for repetition. It can speak back articulately every language dead or living that has been once spoken into it. It can play faultlessly every musical instrument, on the one simple condition that each instrument in turn shall have been previously performed upon in its presence by its admitted master —the violin, let it be said for example by Joachim, the organ by Stainer, the harp by Thomas, the piano by

Rubenstein, the drum by Chip, the horn by Vivier, the violoncello by Piatti, the trumpet by Harper, the clarionet by Lazarus, the double bass by Bottesini. It can play at will besides, either in solo or in full orchestra. It can whisper at one moment and shout the next. It can not only laugh, cry, sing, groan and whistle, but with equal ease, it can echo back such oddly various sounds as hammering, filing, planing, and sand-papering!

Edison's first message to Colonel Gouraud announcing his final triumph over all difficulties, was couched in these emphatic words—"I have perfected the Phonograph. It is a darling."

When, upon that memorable day on which the inventor's newly arrived emissary, Mr. Hamilton, slipped on to the brass mandrel of the instrument at Norwood, the wax cylinder upon the helix of which Edison's voice, ten days before, and some three thousand miles away, had recorded its utterances—Colonel Gouraud has since acknowledged that, although he fully believed, of course, he should hear something, it did not seem to him at all possible that his highly raised expectations could be in any way adequately realised.

Surrounded by his family, at the moment, he felt merely that he was face to face with the most interesting event in his experience. The signal having been then given for starting the machine, the first thing heard—

rather surprisingly—was a cough. It was merely Mr. Edison clearing his throat, but that so very distinctly, that his identity could almost be recognized in his "A-hem!"

There was no room left for doubt, however, that the spoken words were his, that immediately afterwards, in familiar accents, told "Friend Gouraud" that this was the first phonogram yet utilized; that it had been sent across the Atlantic by the North German Lloyd Steamer; that materials, meaning fresh wax cylinders, were sent besides, with which "to talk back to him:" his closing remark, as it seemed, rather invidiously reflecting upon his old friend's penmanship, namely "What a Godsend it will be to receive phonograms from you instead of your writing!"

The sequel to this incident at Norwood will be found vividly enough brought to view in the Frontispiece to the present volume, in which Mr. Edison is revealed, with his grand head and Napoleonic face, listening, through the medium of his wonderful Phonograph, to the voice of his friend, then three thousand miles away from him in England. Being rather deaf, he is doing so, it will be observed, with the bifurcated flexible tubes of the instrument resting the while easily in his ears. Whether any one's hearing be keen or the reverse, in fact, the employment of those same bifurcated elastic tubes of the Phonograph may be looked upon as affording the most agreable means of all, there can be no doubt of this, for hearkening to the infinite variations of sound given forth by its marvellous mechanism.

A trumpet mouthpiece is often, it is true, affixed to the instrument with considerable advantage in the way of increasing the volume of the sounds emanating from it; though always, no doubt, with a more or less distorting effect—just, indeed, as the human voice itself is necessarily distorted if expanded in sonority by its passage through a speaking trumpet.

Side by side, upon any table on which rests this compact little instrument of the Phonograph, there may be placed at pleasure nowadays a box containing a complete Phonogrammic Cabinet—meaning a number of those marvellous wax cylinders on which the voices of picked singers or elocutionists have been recorded by their own articulate vibrations. In this way—had but this invention been given to the world soon enough—there might have been preserved for us, even until now, the rapturous soprano of Malibran, the thrilling tenor of Rubini, the baritone of Ronconi, and the basso profondo of Lablache. Or, going back to a remoter past, we might have listened, still, to what Robert Hall apostrophised, in contrast to each other, as "the rolling thunders of Demosthenes, and the blazing conflagrations of Cicero." Nay, seeing that instrumental music, no less than vocal music and oratory, is absolutely within the Phonograph's power of reproduction, it might just as easily have echoed back to us to-day, the miracles of sound wrought on his weird violin by the wizard bow of Paganini.

As it is, I myself while standing by the side of Colonel Gouraud at one extremity of a long apartment on one of the upper floors of Edison House B in Northumberland Avenue, have heard proceeding from the trumpet mouthpiece of a Phonograph placed on a table at the other end of the room, a Duet between two Cornets-à-piston played originally weeks before on the other side of the Atlantic by a couple of performers on that instrument—every staccato note of which Duet, as repeated now by the vibrations of the silk diaphragm as the needle at its back trailed over the microscopic indentations on the revolving wax cylinder—sounded for all the world as if breathed then for the first time by human lips through the brass tubes of two distinct Cornets-à-piston! More than this, as—by movement after movement—the Duet grew in rapidity and elaboration, the phonographic echo of it all, down to its breathless close, filled one with increasing wonder, by reason, from first to last, of the faultless accuracy of the repetition.

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