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The History of Electrical Engineering

4. MACHINERY FOR THE NEW LIGHT: PART 2

The third article in this series traced the evolution of the magneto-electric generator from its origin as a simple hand-driven device to its successful exploitation in lighthouse illumination. For clarity's sake the description omitted many developments which represented a departure from the main theme, but some of them—particularly the early dynamo-electric machines—were extremely important and are now reviewed here.

C. MACKECHNIE JARVIS, *Member*

An Improved Field System

As long ago as October, 1854, Sóren Hjorth, of Copenhagen, applied for provisional patent protection in this country for an electric generator far in advance of its time not only in respect of constructional detail but also on account of the principles cited by the applicant. Hjorth proposed to include within the compass of a single field-system both permanent magnets and self-excited electromagnets. The initial application was abandoned and Hjorth filed a new application and was granted Patent No. 806 on the 11th April, 1855, under the style of "An Improved Magneto-Electric Battery." The specification includes the following paragraph:

> The action of this battery is as follows: The permanent magnets acting on the armatures brought in succession between their poles induce a current in the coils of the armatures, which current, after having been caused by the commutator to flow in one direction, passes round the electro-magnets, charging the same and acting on the armatures. By the mutual action between the electro-magnets and the armatures an accelerating force is obtained, which in the result produces electricity greater in quantity and intensity than has heretofore been obtained by any similar means.

This remarkable machine, which anticipated Wilde, paved the way towards the discovery of the principle of self-excitation arising from remanent magnetism, but it does not appear to have been developed further at the time.

In November, 1858, J. H. Johnson, a patent agent of London, filed an application for a patent on behalf of "foreigners residing abroad," whose names were not disclosed, for "Improvements in the employment of electricity as a motive power." The application was subsequently abandoned, but the (provisional) specification was published in July, 1859, and in it the following statement appears:

> It is also proposed to employ the electro-magnets in obtaining induced electricity which supplies wholly or partially the electricity necessary for polarizing the electro-magnets, which electricity would otherwise be required to be obtained from batteries or other known sources.

There is no evidence that this machine was made, and nothing further seems to have developed from it.

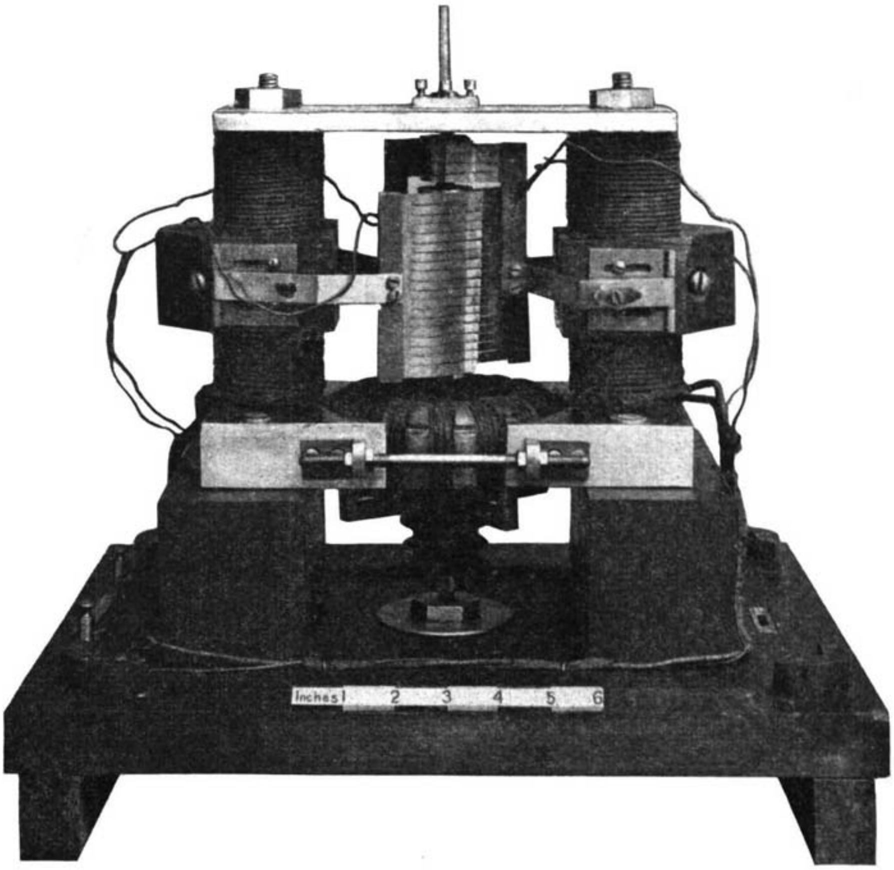
Developments in Armatures

The well-known Siemens "H" or shuttle armature was invented in Germany by Ernst Werner Siemens (1816–1892) and patented provisionally in this country in September, 1856, by his brother, C. W. Siemens, F.R.S. (1823–1883). It was the latter who in 1872 became the first President of The Institution, then known as the Society of Telegraph Engineers. The invention appears in an omnibus electric telegraph specification, where it forms part of a hand-driven magneto-electric machine. The patent application was abandoned, but in accordance with contemporary patent law and procedure the specification was published about six months later. The shuttle armature was used in small generators built by Siemens, Wilde (1861), Ladd (1866) and others. Its merit lay in its relatively small diameter and hence suitability for high-speed working, coupled with improved magnetic performance that resulted from the reduced air-gap and smaller field magnets which the small diameter made possible.

The next development in armature construction occurred in Italy, where Dr. Antonio Pacinotti (1841–1912), afterwards Professor of Physics at the University of Pisa in succession to his father, Luigi, was experimenting with electrical machines. Dr. Pacinotti, in 1860, constructed for the Museum of Technological Physics at the University a model of an electrical machine which, with the aid of an external battery, could be used to demonstrate the operation of an electric motor or of a separately excited generator. The machine is important, because it is generally considered that it was upon it that Gramme based his work. The first description of Pacinotti's invention appeared in 1864,[1] and there the designer referred to a "transversal electro-magnet." This consisted of a ring-pattern armature, comprising a core made in the form of a toothed iron wheel. Between the teeth on the wheel were wound sixteen separate coils joined in series to form a closed circuit. The junction of each pair of wires, sixteen in all, was connected to the commutator. The armature was suspended above a pair of electromagnets, substantially as shown in Fig. 1. Pacinotti's original machine was exhibited some years later, at the Paris Electrical Exhibition of 1881, and earned for its inventor an Award of Merit. He was elected to Honorary Membership of The Institution in 1902.

Passing of the Permanent-Magnet Field System

Meanwhile, in England, Dr. Henry Wilde (1833–1919), of Manchester, was conducting a series of significant experiments, initially in connection with telegraphic



1 *Pacinotti's separately excited electromagnetic machine, 1860, embodying the first toothed armature*

This is of ring construction with a multi-segment commutator.

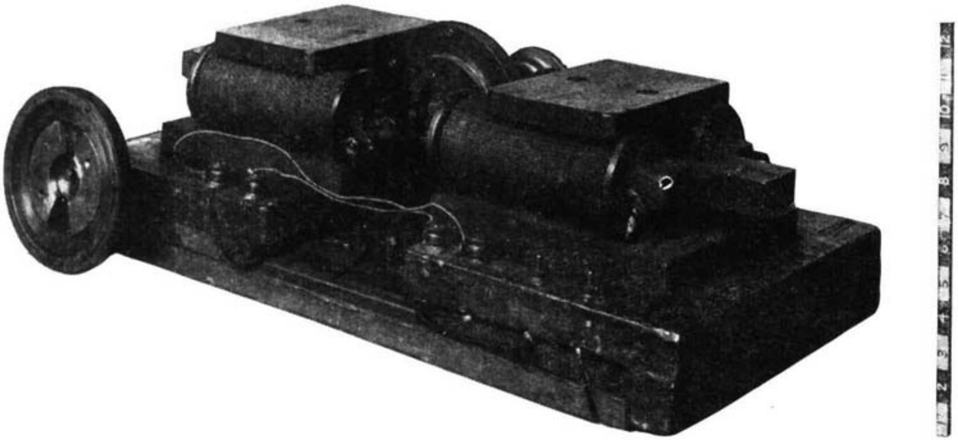
projects. He took out a series of patents from 1861 onwards, the most important being No. 3006 of December, 1863, in which he describes the famous alternator, with its separate permanent-magnet exciter mounted above and driven from a common shaft.

In 1866, Wilde wrote a paper for the Royal Society, to which body it was communicated by Michael Faraday. The title of the paper was "Experimental Researches in Magnetism and Electricity, Part I." It was received on the 26th March, 1866, read on April 26th of the same year, and published in the *Proceedings*.[2] In it Wilde describes "a new and powerful generator of Dynamic Electricity." The paper contains the following significant paragraph:

> The Author directs attention to some new and paradoxical phenomena arising out of Faraday's important discovery of magneto-electric induction, the close consideration of which has resulted in the discovery of a means of producing dynamic electricity in quantities unobtainable by any apparatus hitherto constructed. He has found that an indefinitely small amount of dynamic electricity or of magnetism is capable of evolving an indefinitely large amount of dynamic electricity.

Reference is also made in the paper to Wilde's machines with the separate permanent-magnet exciter, some of which were constructed with commutators for producing direct current. How close Wilde was to the discovery of true self-excitation from remanent magnetism will be appreciated from the foregoing. The paper aroused considerable attention, both in this country and on the Continent. In the author's opinion, it must have come to the immediate notice of the brothers Siemens, one of whom, Charles, was already a Fellow of the Royal Society and the contributor of a paper printed in the same volume of the *Proceedings*.[3] That so important a contribution as Wilde's was immediately sent to Berlin there can be no doubt, for we know from Siemens's published memoirs that the Siemens family, and especially the brothers Charles and Werner, maintained a regular correspondence and also that Charles frequently took out patents in England for his brother's inventions.

In December, 1866, Cornelius and Samuel Alfred Varley (father and son) filed an application for a patent under the title "Improvements in the Means and Apparatus for Generating Electricity." The specification describes a self-excited electromagnetic generator in which the dependence of the field system upon the residual magnetism in building up the field is clearly recognized. The applicants explain that before using the apparatus "an electric current, passed through the coils of the electro-magnets, secures a small amount of permanent magnetism to their cores." The specification was not published until July, 1867, and this fact has tended to obscure the legitimate claims of S. A. Varley, the inventor, for a share in the credit for recognizing the fact that residual magnetism could provide the "indefinitely small amount of . . . magnetism" postulated by Wilde earlier in the same year.



2 *S. A. Varley's original self-excited dynamo, 1866*

The armature comprises two coils encased in a brass disc.

[By courtesy of the Director of the Science Museum, South Kensington.]

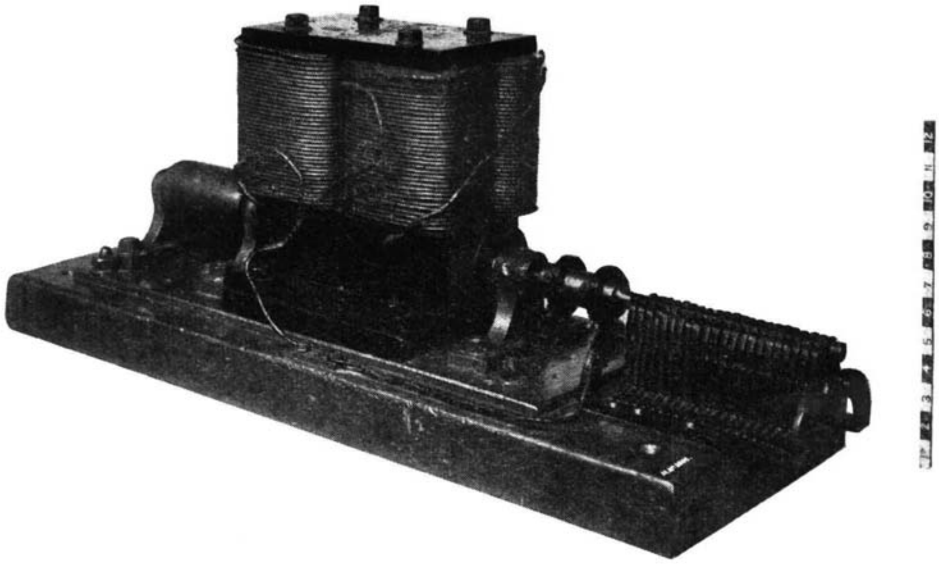
Simultaneously, in Berlin in the same month, Dr. Werner Siemens submitted a paper to the Berlin Academy of Sciences, before whom it was read on the 17th January, 1867.[4] The title in the English translation is "On the conversion of mechanical energy into electric current without permanent magnets." Siemens described a machine which operates on the same principle as that described by Varley, and in his paper acknowledged his indebtedness to Wilde in the following terms:

> Lately, Wilde of Birmingham has considerably increased the efficiency of magneto-electric machines by combining in one machine two magneto machines of my above described construction.* He provides the larger of these machines with an electromagnet in the place of a steel magnet, and uses the other to effect continuous magnetisation of this electro-magnet. It can easily be perceived that by means of this combination Wilde has considerably diminished the above defects of the steel magnet machine. Setting aside the inconvenience of employing two inductors at the same time to produce one current, his apparatus is dependent on the uncertain performance of the steel magnet.

It is difficult to believe that Siemens seriously considered that the residual magnetism in his soft iron electromagnet was more certain than the magnetism in a steel magnet although none would deny the greater convenience of the arrangement. Werner Siemens's Berlin paper was not published for several months, and in the meantime his conclusions were embodied in a paper communicated to the Royal Society of London[5] on the 14th February, 1867, by his brother Charles, who exhibited with it a hand-driven generator.

* Siemens here refers to the shuttle armature which he had introduced in 1856.

At the same meeting, another pioneer, Professor (afterwards Sir Charles) Wheatstone, F.R.S. (1802–1875) read a paper on the same subject,[6] and also exhibited a hand-driven generator similar to that of Siemens except in respect of the winding details. Wilde was present at this meeting and gave an account of it to the Manchester Literary and Philosophical Society five days later, in reply to a question "whether any member was acquainted with particulars of a remarkable discovery in connection with the conversion of dynamical into electrical force by M. Siemens and Dr. Wheatstone, a brief notice of which appeared in the *Athenaeum* of February 16th."[7] Wilde described the machines he had seen and commented "that having himself sometime ago made similar experiments to Siemens and Wheatstone, he came to the



3 *Self-excited generator exhibited by C. W. Siemens at a meeting of the Royal Society in London on the 14th February, 1867*

This machine employs a shuttle, or "H," armature.

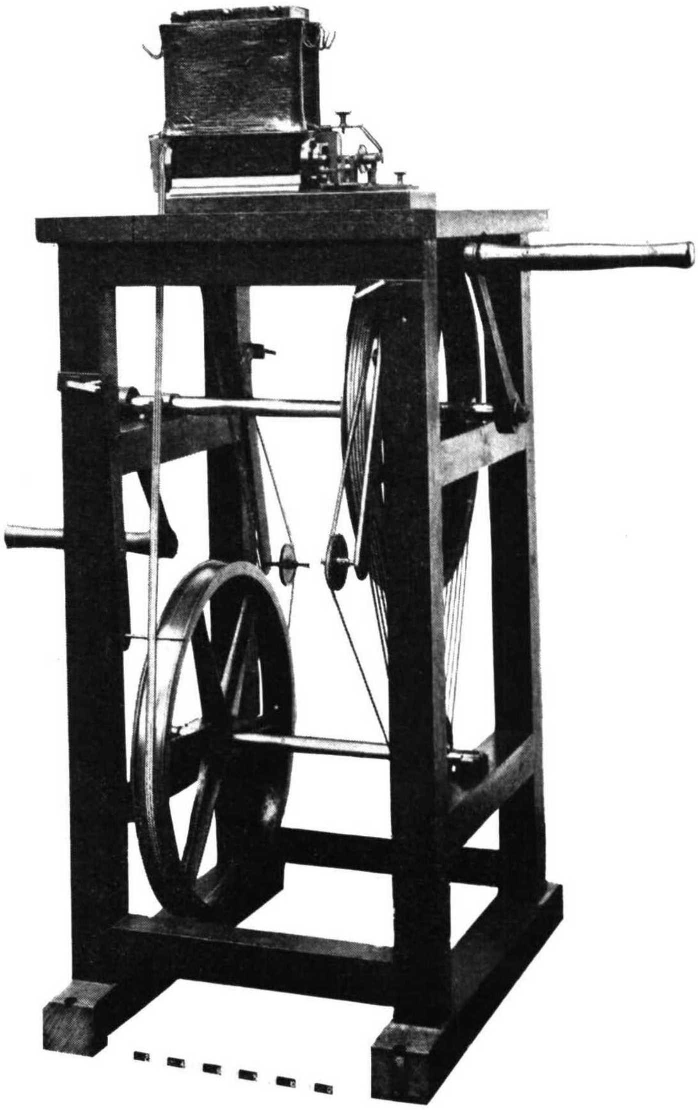
[By courtesy of the Director of the Science Museum, South Kensington.]

conclusion that in the present state of our electrical knowledge the difficulty of utilizing current after it had passed through the coils of the electro-magnet when excited by intermittent currents was insuperable." He was of the opinion that although the results obtained were undoubtedly very interesting from a scientific point of view, the practical results were inferior to those of separate excitation.

In interpreting this statement, it must be remembered that machines of this period with Siemens "H" armatures were provided with two-segment commutators, and thus delivered a pulsating unidirectional current. The first electromagnetic generators were of the series-wound pattern, and the impedance of the field windings, especially at the higher speeds, would have been considerable. This difficulty was inseparable from the shuttle armature, and it is therefore not surprising to find that as late as 1873 the Siemens brothers were following the practice of Wilde in using a separate exciter for the field of the main generator. Such a combination was shown at the Vienna Exhibition of that year, and this suggests that only in matters of publicity was Wilde at this time behind his contemporaries on the Continent.

Another matter which Wilde disclosed to the Manchester meeting was that he had received a letter written on the 9th November, 1866, by an American correspondent who indicated that he, too, had discovered the principle of self-excitation without the use of permanent magnets. The letter was from Moses G. Farmer, of Salem, Massachusetts, a name well known among the early electrical manufacturers in the United States. The relevant passage reads as follows: "I have built a small machine in which a current from the thermo battery excites the electro-magnet of your machine to start it, and after the machine is in action, a branch from the current of the magneto (i.e. armature) passes through its own electromagnet, and this supplies the magnetism required." The reference to a branch current indicated that the generator was, in effect, shunt-wound, and that it would thus appear to anticipate the use of the shunt connection by Wheatstone. Wilde's paper to the Royal Society in April, 1866, was primarily responsible for stimulating in the minds of others a train of thought which led to the almost simultaneous realization of the principle of self-excitation by three or four independent inventors.

In March, 1867, there occurred an event which was to have great significance nearly forty years later, when credit for the invention of the dynamo was claimed and disputed. This was the publication by Charles Brooke, F.R.S. (1804–1879), of a paper[8] before the Royal Society, in which the compound term "dynamo-electric" was first employed. Brooke used it in the generic sense to denote apparatus capable of converting mechanical into electrical energy and he used the term "electro-dynamic" conversely in relation to the action of electric motors. In his paper Brooke quoted as examples of dynamo-electric machines the glass-plate machines of Holtz "and the



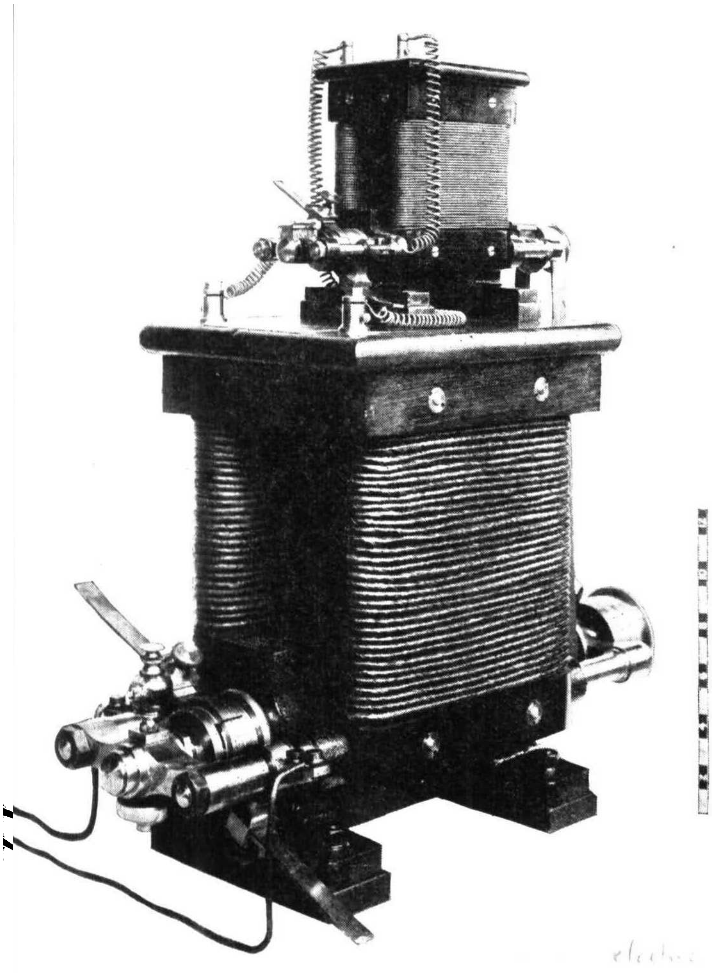
4 *Wheatstone's self-excited generator exhibited at a meeting of the Royal Society on the 14th February, 1867*

This machine has a shuttle armature.

cognate machines of Wilde, Wheatstone, Siemens and Ladd."

For obvious reasons self-excited generators tended to be popular, and became known as dynamo-electric machines, the term being shortened by common consent to dynamo. Such machines were primarily suitable for producing direct current, and thus the expression became associated in a specific sense with d.c. generators. Subsequent writers of the period used the expression to distinguish generators with wound field systems from those of permanent-magnet construction, which were called magneto-electric machines.

The magnet cores of the early dynamos were not



5 *Wilde's famous combination of an electromagnetic generator with magneto-electric exciter, 1867*

Both armatures are of the Siemens "H" type.

[*Crown copyright. From an exhibit in the Science Museum, South Kensington.*]

laminated, and since the frequency of the current pulsations often amounted to upwards of 60 per second, it is not surprising that heating constituted a major problem and limited the period of continuous operation from cold to a maximum of about three hours. A number of Wilde's dynamos were purchased by Elkington & Co., of Birmingham, for electroplating purposes. According to Wilde, Mr. Charles E. Ryder, the factory manager, devised a method of water cooling for the field magnets and fed the heated water to a boiler hot-well! A water cooling system was also used by Siemens and Halske on one of the dynamos exhibited in Vienna in 1873.

The dynamo of William Ladd, to which reference has frequently been made, was a composite machine with two separate shuttle armatures revolving in a common magnet system. One armature supplied the excitation for the field magnet whilst the second, and larger, fed the external circuit. This machine was constructed in 1867 and exhibited at the Paris Exhibition of that year, where it was the subject of an award.

The Gramme Ring and the Drum Armature

It is generally considered that the credit for producing the first practical dynamo yielding a truly continuous current is due to Zénobie Théophile Gramme (1826–1901). Gramme was a native of Belgium, but most of his work was carried out in Paris, where in 1870 he produced his first generator. He developed a ring armature using soft iron wire, an arrangement which had previously been advocated by Joseph Henry (1797–1878) for the construction of the magnets of telegraph relays. In principle, Gramme's armature followed that of Pacinotti; the winding was continuous, and was tapped at intervals for connection to a multi-segment commutator. During the winding of the core, the iron wire was caused to pass through a bath of bituminous compound, which insulated the individual strands and thus considerably reduced eddy currents.

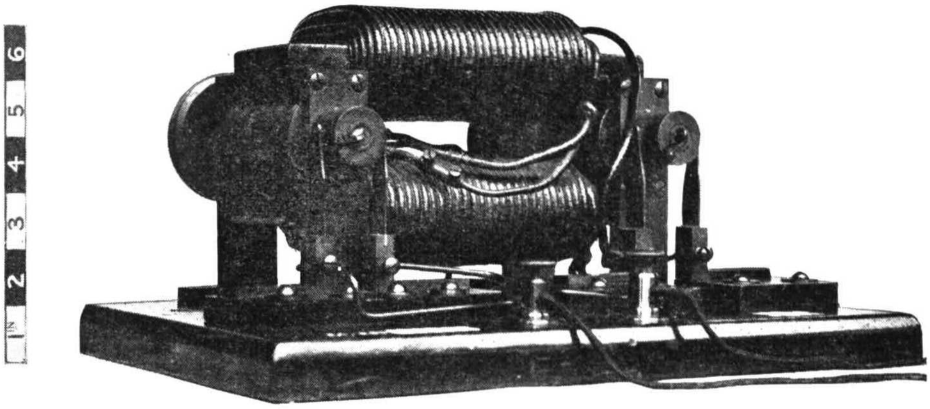
The first Gramme machine was exhibited before the Paris Académie des Sciences in July, 1871. It formed the subject of several patents in this country, the first of which was No. 917 of 1870, and there were others taken out in the name of one of Gramme's Paris associates, Hippolyte Fontaine. Within a short time, the Gramme organization was manufacturing dynamos in large numbers in Paris, and similar machines were constructed under licence in a number of countries, including England.

In 1873 a Gramme dynamo was brought from Paris to London in connection with lighting trials in the upper lantern of the clock-tower at Westminster, where the electric light was in competition with Wigham's improved gas light. From this time forward, numerous firms entered the field with variations on the Gramme theme, and among the best known in this country were those of Bürgin, Brush and Wallace Farmer.

In the United States the Gramme dynamo was made by the Fuller Electrical Company, and in England by the British Telegraph Manufactory under the direction of Robert Henry Sabine (1837–1884), one of the eight founder members of the Society of Telegraph Engineers. Sabine, who was a son-in-law of Sir Charles Wheatstone, had worked with C. W. Siemens in London and Werner Siemens in Berlin, and also with Latimer Clark and Wheatstone.

The Bürgin dynamo originated with Emile Bürgin of Basle, Switzerland, and consisted of a series of four or more squares of iron wire, each carrying four coils (one per side) wound in the conventional ring manner. The machine, which was the subject of several English patents from 1875 onwards, was a great improvement on the early Gramme dynamos, in that the "rings" were spaced to produce a machine greater longitudinally than the Gramme, the coils being relatively small in diameter and therefore less subject to heating in operation.

An English pioneer, Col. Rookes Evelyn Bell Crompton, F.R.S. (1845–1940), saw the machine about 1880, and perceived in it the essence of a successful dynamo. In Crompton's hands the armature core was changed in shape from square to hexagonal and provided with six



6 *Ladd's twin-armature dynamo with a common field system, 1867*

The machine is self-exciting, the first armature acting as an exciter for the field system of the second.

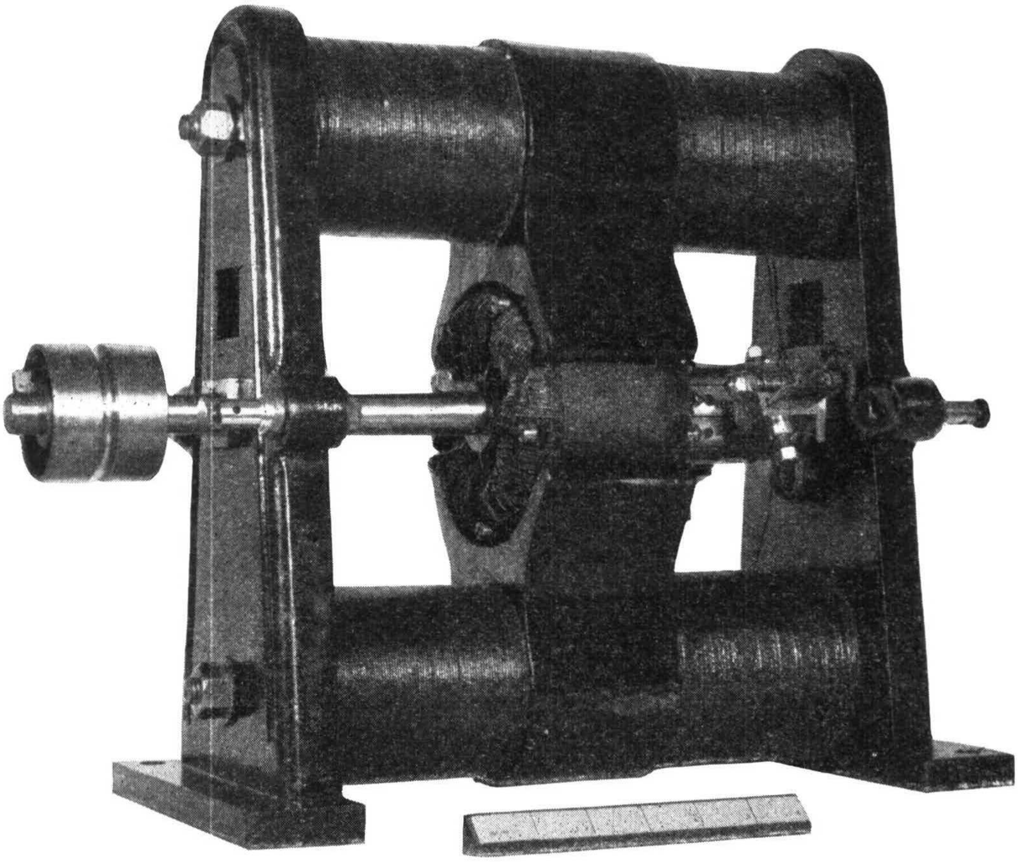
[*Crown copyright. From an exhibit in the Science Museum, South Kensington.*]

coils per ring. The number of rings per armature was increased to ten. The rings were supported on the spindle by means of a spoked frame, and each successive ring was displaced angularly from its predecessor by an amount equal to one-sixtieth of the circumference. Although the armature of the Crompton–Bürgin dynamo possessed the great advantage of good ventilation, the induction between neighbouring rings introduced difficulties, and after a few years the arrangement was abandoned in favour of a modified Gramme ring.

Professor Gisbert Kapp (1852–1922) was for a time Chief Engineer in the Crompton works at Chelmsford and joint patentee with Crompton in 1882 of the compound field winding for "maintaining a constant electromotive force at the terminals of dynamo machines." It is generally conceded that the compound winding was first used about 1878–79 by the American pioneer electrician Charles Francis Brush (1849–1929). Brush added a shunt winding which he called a "teazer" to electroplating generators in order positively to prevent reversal of the direction of current through the baths.

The success of the Gramme ring was viewed with concern in Berlin, but it was not long before an answer was found in the form of the drum armature invented by Friedrich von Hefner Alteneck, chief designer to Siemens and Halske, in 1872 and patented in England in the following year. In the first machines of this class the armatures were drums of wood with windings held in position by pegs driven into the surface of the wood cylinder. Subsequently, the wooden drums were overwound with iron wire, on top of which the windings were located as before.

Ten years later, in January, 1883, Dr. Paget Higgs, of the Higgs Electric Light and Power Co., wrote in *The Electrician*:[9] "At the present stage of electric work, however, I should be surprised to see any maker putting iron into his armature, where that armature has to carry over 100 amperes, not so much on account of the loss of efficiency in working as for the reason that the machine must become very cumbrous and costly to make."



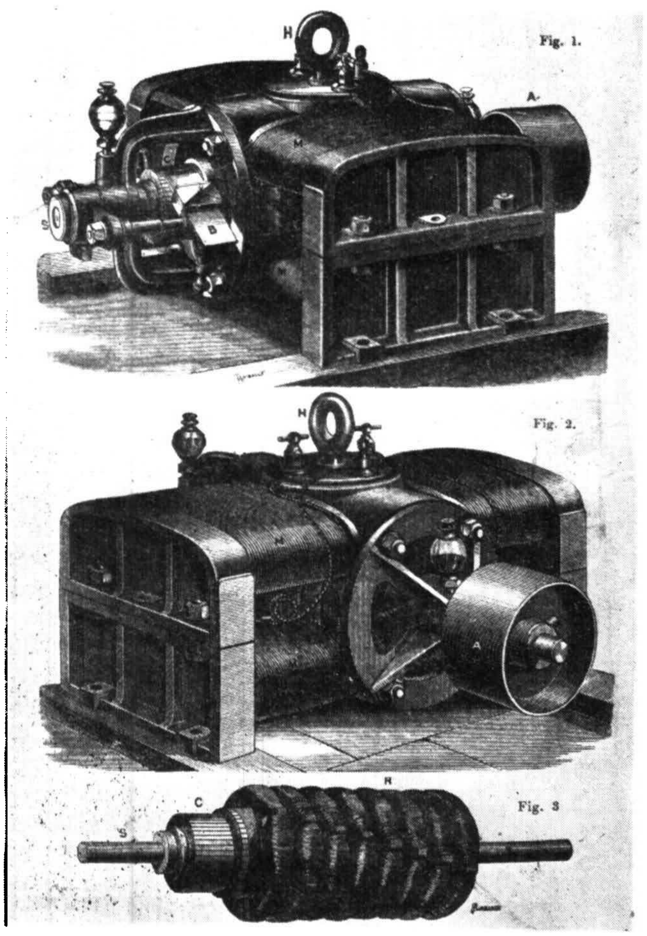
7 *An early Gramme dynamo with ring armature, 1870–71*
[*By courtesy of the Director of the Science Museum, South Kensington.*]

It is unnecessary to point out that the drum armature possesses the advantage that the greater part of the conductor is usefully employed, unlike the Gramme ring, where the inside portion of every turn is ineffective. Many years elapsed before the best combinations of windings and commutator segments were evolved, but the invention has proved of lasting value in the realm of dynamo design. The early drum armatures were not by any means free from troubles, among which were excessive sparking, due to the unsymmetrical arrangement of the windings first used by von Hefner Alteneck, a tendency to be unduly sensitive to fluctuating loads (which again caused sparking at the brushes), and heating of the armature windings, which rose in temperature much more rapidly than the field windings.

One of the most successful of the early American companies was that founded by Brush. This played an active part in the development of electric lighting and public supply, both of which subjects will be dealt with in subsequent articles in this series. Brush's first machines were produced in 1877–78, and his first English patent is that of 1878, which relates to a dynamo machine with a ring armature of special design. A branch of the Company, known as the Anglo-American Brush Electric Light Corporation, was floated in this country about 1882 and was followed by provincial subsidiaries.

8 *Crompton's improved Bürgin dynamo, 1881–82, employing multiple hexagonal armature cores of ring construction*

[*By courtesy of Crompton Parkinson, Ltd.*]



The following excerpt from an editorial article on "The Electric Light" which appeared in *Engineering* on the 19th October, 1877, is of considerable interest as reflecting informed contemporary opinion. The article was unsigned but was almost certainly written by James Dredge.

> Gramme produced a machine, which at the time (viz. 1873), was the most powerful in existence as well as the most economical dynamo-electric machine, and bid fair to revolutionise the whole science of illumination and to stand unrivalled as a producer of electricity. It was said and believed that the Gramme machine had solved the long-sought problem of how to produce cheap electricity.
>
> At the Loan Collection (i.e. Exhibition) at South Kensington held in 1876, the public had an opportunity of seeing machines of Société Alliance, M. Gramme and Messrs. Siemens at work, and all must have been struck by the small size of the Siemens machine. Light from the Siemens and Gramme machines was apparently of the same intensity, but the Siemens machine was a quarter of the size of Gramme's and about one-eighth of the weight.
>
> In consequence of this Exhibition, the Corporation of Trinity House invited the makers of dynamos to a competitive trial. The English representatives of Gramme, Siemens and Wilde accepted. The French proprietors of the Gramme dynamo refused to compete. Conditions of the trial were laid down by Trinity House. Wilde would not agree, and withdrew. These trials were carried out under the direction of Professor Tyndall, F.R.S., . . . at the South Foreland in 1877. The upper and lower towers were each equipped with Gramme and Siemens arc lights, and every reasonable combination could be obtained. These trials went unmistakably in favour of the Siemens machine.
>
> . . . There can be no doubt with apparatus producing so great an intensity of light, and at so small a cost that the time is close at hand, if it has not already come, when ocean-going steamers will have to carry electric lights for the prevention of collisions at night, for discovering other vessels, rocks, shoal water, or land from two to three miles ahead, and for facilitating the operation of taking in or discharging cargo at night. . . . For ships of war, the electric light is of still greater value as a protection against the attacks of torpedo boats at night, and for this purpose, is being fitted to several of the new ships in Her Majesty's Navy, and it is employed for this purpose in the ships of the French, Russian and Spanish navies.
>
> . . . We believe there is a great future for electrical illumination, and as fresh improvements, and new invention will arise, it will become of more general application. Perhaps the time is not far distant when electricity will be, as an illuminating agent, as familiar to the public as gas is now, though we must confess that we do not consider the subject has advanced so far as to justify the depression in gas shares with which a recent ingenious invention, known as the electric candle, was lately accompanied.

The Inventor of the "Dynamo"

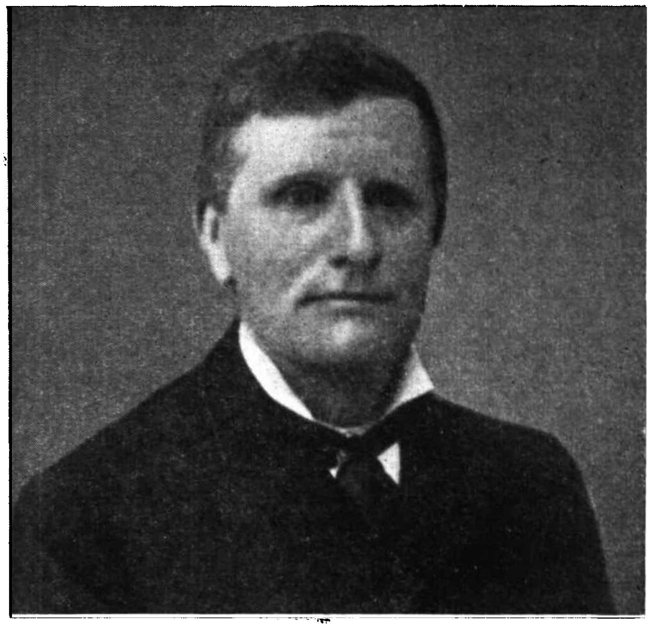
In later years, after the events outlined above had passed into history, the part played by Wilde, who had outlived most of his contemporaries, tended to become obscured and frequently overlooked, and this was undoubtedly responsible for the somewhat uncompromising attitude he displayed during the early years of the present century.

The first incident arose when Wilde was awarded the Albert Medal of the Society of Arts in June, 1900. The award was for "the discovery and practical demonstration of the indefinite increase of the magnetic and electric forces from quantities indefinitely small." The citation proceeded: "The Council also recognizes the fact that your discovery is the principle on which the modern dynamo is based, and they believe that its value may be fitly recognized by the award they have now made to you." Wilde objected strenuously to the terms of the award, on the ground that they did not specifically state that he was the inventor of the dynamo-electric machine. Through his solicitors, he sought to compel the Society to withhold publication of the award until the terms could be agreed, but, notwithstanding the fact that such a situation had arisen, the Society released a statement, which appeared in the Press, and a somewhat disagreeable situation resulted. The Society, on the advice of its referees, declined to meet Wilde's wishes in respect of his claim to have invented the dynamo, and, as a compromise, modified the terms of the award to include a reference to the electric searchlight and electro-deposition of metals, with which he was prominently associated. Wilde was not prepared to agree, and the incident was closed when the Society created a precedent by sending the gold medal through the post. On previous occasions recipients had been presented with the medal by the Prince of Wales, afterwards King Edward VII. Wilde thereupon published the correspondence[10] and presented his Albert Medal to The Institution.

About this time, Murray's "New English Dictionary on Historical Principles" was in course of publication, and the editor invoked the aid of Professor S. P. Thompson, F.R.S., in respect of matters concerning electricity and magnetism.[11] On Thompson's authority, the printed version of the dictionary stated that the first use of the term "dynamo-electric" was by Werner Siemens in his paper before the Berlin Academy in January, 1867, in connection with a machine he had invented. Wilde again entered an objection, and threatened an injunction against the printers and the editor. He raised further objections to statements of a rather general nature in Thompson's "Michael Faraday" and in the same author's "Dynamo-Electric Machinery," a new edition of which was then known to be in course of preparation.

In 1902, the electrical world was startled by the sensational news that a writ for libel had been issued by Dr. Wilde against Professor Thompson in respect of statements appearing in the earlier editions of Thompson's books. Wilde claimed, substantially, that he was the inventor of the machine commonly known as the dynamo, that the term "dynamo-electric" coined by Brooke referred expressly to his machine, and further that any statements to the contrary, and in particular those which sought to give credit elsewhere, ran counter to fact and were damaging to his reputation.

Thompson was advised to enter a demurrer pleading that the Statement of Claim in the action should be set aside on the ground that it showed no cause for proceedings and was vexatious. These preliminary proceedings went in favour of Thompson on purely legal grounds, and the action was dismissed. The judgment was upheld in the Court of Appeal, and there the matter might have ended, but for the fact that Thompson published in *The Electrician*[12] a long letter explaining his position. Wilde, through his solicitors, replied, and the correspondence continued for some weeks until Thompson withdrew.



9 *Dr. Henry Wilde, F.R.S. (1833–1919)*

Among many other benefactions, Dr. Wilde founded the Wilde Benevolent Trust Fund of The Institution. This portrait taken at the age of 56 is reproduced by courtesy of the Manchester Literary and Philosophical Society. It is probably the only surviving likeness.

Nothing that transpired can affect the high reputations which the disputants enjoyed, and The Institution honours the memory of both. Thompson, a D.Sc., was President for the year 1899, and Wilde, also an Hon. D.Sc. and Hon. D.C.L., was an Honorary Member of The Institution from 1898 until his death in 1919. Both were Fellows of the Royal Society. Obviously, memories on both sides were at fault, but as a result of the correspondence Wilde's solicitors published an earlier letter[13] from Thompson to Wilde concerning the position of Siemens, which otherwise might never have been disclosed. Thompson had written: "In making the former statement that this word (dynamo-electric) was first used by Werner Siemens in his paper at the Berlin Academy of Science, I was misled by Siemens' own subsequent allegation that he had done so. As, however, in the printed paper the word does not appear, and as (on enquiry in Berlin) no one remembers that he did so, when communicating the paper, it is clear that his statement cannot be accepted as historic."

Wilde's pioneer work on the marine searchlight commenced in the 1870's. By 1876 he had persuaded the Admiralty to permit full-scale trials, which were successful, as the following minute on "Wilde's Electromagnetic Light" shows: "Rear Admiral Sir F. Beauchamp Seymour, K.C.B., to the Lords Commissioners of the Admiralty November 10th 1876: 'The electro-magnetic machine fitted to the Minotaur by Messrs. Wilde & Co. has now been in use for seven months and having thoroughly tried it under all circumstances of wind and weather, including fog, I am enabled to give my testimony to its great value.' "

References

1 *Il Nuovo Cimento*, 1864.
2 *Proceedings of the Royal Society*, 1866, 15, p. 107.
3 *Ibid.*, p. 71.
4 *Monatsberichte Akademie der Wissenschaften*, Berlin, 1867, p. 56.
5 *Proceedings of the Royal Society*, 1867, 15, p. 367.
6 *Ibid.*, p. 369.
7 *Proceedings of the Manchester Literary and Philosophical Society*, 1866–67, 6, p. 103.
8 *Proceedings of the Royal Society*, 1867, 15, p. 408.
9 *The Electrician*, 1883, 10, p. 179.
10 "Correspondence in the Matter of the Society of Arts and Henry Wilde, D.Sc., F.R.S." (Manchester, 1900).
11 Thompson, Jane S. and Helen G.: "Silvanus Phillips Thompson, His Life and Letters" (T. Fisher Unwin, 1920), p. 99.
12 *The Electrician*, 1903, 52, p. 60.
13 *Ibid.*, p. 177.

The Measurements Section discuss

SURGE DIVERTERS

On the 19th April, 1955, Mr. R. Davis, M.Sc., Member, opened a discussion on "The Measurement of Impulse Voltages and Currents with special reference to the Testing of Surge Diverters" at a meeting of the Measurements Section. His remarks, and the subsequent discussion, are summarized below.

MR. DAVIS began by defining a surge diverter as a 2-terminal device usually located between a high-voltage line and earth close to equipment which may be exposed to high-voltage surges, of atmospheric origin or arising from switching operations. In the form most commonly used it consists of a number of silicon-carbide discs in series, one end of the column being connected to one terminal and to earth, and the other via an isolating gap to the second terminal, which is connected to the line. The discs and gap structure are housed in a weatherproof porcelain shield. Modification to this sample structural scheme may include the use of a multi-electrode gap structure and the addition of impedances in parallel with individual gaps to secure uniform distribution of the normal operating voltage across them. The function of the isolating gap is to ensure that under normal operating conditions the energy dissipated in the conducting column is a minimum; when a voltage of predetermined minimum amplitude is applied to the terminals, breakdown of the gap should occur and the column should provide a low-impedance path to earth; when the current has fallen to a low value it is interrupted through deionization of the gap, and the normal operating condition of the surge diverter should be restored. The low-impedance path to earth is provided by the silicon carbide, the current through which increases as the third or fourth power of the voltage across it.

Impulse tests on surge diverters should provide evidence that they will restrict the over-voltage appearing at the terminals of protected equipment to a predetermined value; they provide no evidence of the adequacy of weatherproofing or of satisfactory performance under normal operating conditions.

To assess the adequacy of the diverter as a protective device, three types of test have been used, namely

(*a*) The measurement of the breakdown voltage of the isolating gap.

(*b*) The measurement of the maximum voltage across the diverter when the isolating gap has broken down and the device is passing a surge current of prescribed shape and amplitude.

(*c*) The simultaneous application of a power-frequency and impulse voltage—the operating-duty test.

Test (*a*) is made first at a voltage provided by the normal impulse generator, which causes breakdown at or beyond the peak, and secondly at a voltage and wavefront steepness high enough to cause breakdown on the wavefront. The breakdown voltage is usually measured with a cathode-ray oscillograph in association with a voltage divider. The oscillograph method is probably essential for the wavefront breakdown test and for measurement accurate to a few per cent a voltage divider with a constant ratio over a wide frequency band is necessary. This performance can be obtained with both capacitive and resistive dividers, the latter being preferably of the shielded type. Special precautions are necessary to ensure that the potential points are taken as close as possible to the diverter terminal, so that the voltage in an impedance carrying a large current is not measured.

In addition to voltage measurements, test (*b*) requires surge-current measurements and the provision of special circuits to produce the required current waves. The current is calculated from the voltage drop across a non-inductive resistor in series with the surge diverter. The resistor should be capable of passing the prescribed current without appreciable change in value through heating. The time-constant requirements are not excessively stringent, since the current waveshape is either a 5/10 or 10/20 microsec wave or a flat-topped wave. Care must be taken to ensure that the attainment of a reasonably low self-inductance in the measuring resistor is not vitiated by inattention to the need for a low mutual inductance between the voltage and current circuits of the resistor, since mutual inductance has in the past led to gross overestimation of large transient currents. For the production of current waves of shape $n/2n$, e.g. half sine waves, a capacitance C charged to a voltage V is discharged through the surge diverter via an inductance L. To secure the required amplitude and value of n the