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ELIHU THOMSON[1]
1853–1937

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FOR one destined to apply his genius largely toward harnessing electricity for the work and comfort of man, the decade beginning with 1850 was a timely period in which to be born. The preceding half century had witnessed the fundamental discoveries which underlie the utilization of electricity, and imaginative minds had begun to direct these discoveries into the broad channels of practical and commercial employment.

In the development of the electrical art this first half of the nineteenth century was a remarkable fifty years, and because it provided the foundation for the practical achievements which came in the second half, a review of it helps to give perspective to this memoir on Elihu Thomson.

The century opened auspiciously with Volta's discovery of the voltaic cell, and with the demonstration by Nicholson and Carlisle of electrolysis. In 1820 Oersted announced his discovery that an electric current has the power to deflect a magnetic needle. In this same year Ampere brilliantly elucidated Oersted's discovery by giving mathematical expression to the forces produced by electric currents. Six years later Ohm announced the formulation of his law that current is proportional to the electromotive force, and

[1] Condensed from a memoir presented to the National Academy of Sciences.

twenty years later Gauss and Weber invented an acceptable system of electrical and magnetic units.

Meanwhile, Faraday had begun the epochal researches which were to lay the foundations of electrical engineering. In 1821 he had succeeded in making a wire revolve about a magnet and a magnet about a wire, and ten years later, almost simultaneously with Henry in America, he made the great discovery underlying almost all electrical machinery—electromagnetic induction. This led him to the mechanical production of a steady electric current by revolving a copper disc between the poles of a magnet.

Minds with a practical bent were quick to follow the road which Faraday and Henry had pointed out. By 1850, the electric motor had been demonstrated, the commutator had been devised, the electric arc had been experimentally used for lighting, and efforts had been made to drive boats, buggies and locomotives by electricity. But the conquest of electric power was still thwarted by practical difficulties; only in the form of the telegraph and a few other devices had electricity been put to work effectively.

It was during this stage in the development of the electrical arc that Elihu Thomson was born in 1853, and it was not until he had embarked upon his professional career at the tender age of 17 and was ready to join the creative thrust that the drive toward economic utilization of electric power had really begun to gain ground rapidly. In 1875, five years after Gramme had built his ring-wound armature, and along with Siemens had made the dynamo a practical machine, Thomson had built a dynamo and by 1879 he had invented and patented a three-coil arc dynamo—a pioneer three-phase generator. He thus early took prominent place in the brilliant group, including Brush, Edison, Siemens, Stanley, Tesla, Van Depoele, Weston and others, which was to solve the problem of generating adequate current. The electrical tide was approaching its flood and Thomson was ready—with consequences important to the development of the electrical industry.

The young man who thus auspiciously began his career in Philadelphia was born in Manchester, England, on March 29, 1853, of a Scotch father, Daniel, and an English mother, Mary Rhodes. Elihu was the second son of the family, which ultimately was to total eleven children, six boys and five girls. Four years after Elihu's birth, the panic of 1857 struck England and his parents, moved by the resulting scarcity of work, decided to emigrate to America, which they did in 1858, settling in Philadelphia.

In February, 1866, Elihu was admitted to the Central High School in that city, even though he lacked several weeks of having attained the required age. Four years later he was graduated as fourth honor man and accepted employment in a commercial laboratory where analyses were made of iron ore and other minerals. He remained in this post for about six months and then returned to Central High School in the fall as "Adjunct to the Department of Chemistry" at a salary of $500 per year.[2]

One of the senior professors whom he assisted in this post was Edwin J. Houston, who held the chair of physical geography and natural philosophy, and the two were soon engaged in collaborative investigations which led to a long partnership. The first publication growing out of their research was a paper "On a New Connection for the Induction Coil," contributed by Professor Houston to the June, 1871, issue of the *Journal of the Franklin Institute*. The paper contained an account of Thomson's observations of sparks drawn from grounded waterpipes during the operation of a nearby induction coil. Although he did not recognize the significance of the evidence at the time, he had clearly observed the propagation of electrical waves through space. When, in 1875, Edison announced a new "etheric" force which he described as non-electrical, Professor Thomson was primed to dispute his conclusions, for he wrote later:

> I had proposed to Houston that we carry on these experiments and show definitely that the so-called "etheric" force that Edison had announced in the papers was merely an electrical phenomenon. At this time I took upon myself the enlargement of the scale of the experiments, so as actually to obtain a very definite result. This was carried out, as follows, in 1875. A 6-inch spark Ruhmkorff coil was set up with one terminal connected by a wire about 5 feet long to a large tin vessel mounted on a glass jar on the lecture table. When the coil was in operation, sparks were allowed to jump across the terminals of the coil itself, these sparks being about $1\frac{1}{2}$ inches to 2 inches long and having the character of condenser sparks. When the coil was in action, I explored the whole building throughout the several floors and then went up to the top of the building to the observatory, where Professor Snyder had charge of the astronomical instruments. It was found that tiny sparks could be obtained from metal objects wherever they were, in the cases or outside, from the door-knobs or from apparatus, by the simple expedient of shading from the light and detecting the tiny sparks with a pointed pencil by applying it, say, to the door-knob. I recognized clearly that this was a manifestation of electric waves passed through space, and I also understood that a system of communication might readily be based thereon.[3]

A description of this experiment was communicated to the Franklin Institute by Professor Houston and printed in its *Journal* for January, 1876. With the

[2] "The Philadelphia Period in the Life of Professor Elihu Thomson," by John Louis Haney. *The Barnwell Bulletin* of Central High School, February, 1939.

[3] Unpublished notes of Professor Thomson in the files of J. A. McManus, General Electric Company, Lynn, Mass.

exception of Joseph Henry's experiments, which were unpublished, here was one of the first experimental demonstrations of the validity of Maxwell's theory, and here, too, was an example of Professor Thomson's extraordinary intuition anticipating the wireless transmission of signals over a decade before Hertz demonstrated electromagnetic waves and twenty odd years before Marconi received his patent on "telegraphy without wires."

Again in Thomson's nineteenth year, the *Journal of the Franklin Institute,* August, 1871, carried an account, written jointly by Thomson and Houston of further original work. This paper, "On the Change of Color Produced in Certain Chemical Compounds by Heat," was a pioneer discussion of this phenomenon. His next important paper, "On the Inhalation of Nitrous Oxide, Hydrogen, and other Gases and Gaseous Mixtures" appeared in the *Philadelphia Medical Times,* November 15, 1873, and foreshadowed his later work on the use of helium in diving and caisson work.

By 1877 Thomson was swinging into his full stride. He had received the master of arts degree from his institution and had been appointed professor of chemistry and mechanics. His capacity to work productively in a variety of fields had been amply demonstrated by creative work in both chemistry and physics. He had, during a series of successful lectures at the Franklin Institute, anticipated the system of electric-welding he was later to patent, he had conceived the idea of a cream separator, and he had described the operation of tuning one electrical circuit to another.

Thomson regarded his "more serious interest in electrical applications"[4] as beginning in 1878 with a series of tests on dynamos then in commercial use. This report had been preceded in the *Journal of the Franklin Institute* by papers on the relaying of the telephone and on "A New System of Electric Lighting and a New Form of Electric Lamp," and it was followed in 1879 by "Circumstances Influencing the Efficiency of Dynamo Electric Machines" published jointly with Professor Houston in the *Proceedings* of the American Philosophical Society. This paper, as did the report to the Franklin Institute, emphasized the advantage of low internal resistance in a dynamo as compared to the resistance of the external circuit.

It was in 1879 that he and Houston built a dynamo with three-phase winding. This machine, patented in 1880 and now at the Smithsonian Institution, was known as the "bakery machine" because of its use for lighting a large bakery in Philadelphia. "This is the machine," Thomson once noted, "upon which the Thomson-Houston Electric Company was based. . . . I think this is a very important invention, inasmuch as the great power generators of to-day are three-phase dynamo machines with three-phase armature winding. . . ."[5]

Having made fundamental improvements in the dynamo, Thomson and Houston, prompted by the commercial application of arc lighting by Brush, rapidly rounded out a complete and reliable arc-lighting system. They devised a constant current regulator (1881), an air blast method to extinguish or prevent the arc tending to occur when an electric circuit is opened (1882), and the magnetic blow-out (1883), which employs a magnetic field to extinguish an arc.

Of this arc-lighting development Dr. Dugald C. Jackson, the well-known electrical engineer, has said:

> Arc lighting has largely been superseded by later forms of electrical illumination, but I am personally inclined to put forward this invention of the automatically regulated dynamo for arc-lighting service as one of Thomson's most important, on account of its influence on his own work and the development of his opportunities. The invention was made when he was still in his twenties. It was carried through substantially on his own responsibility except for meager financial aid, and drew out at this early age, at least in some degree, those qualities of originality, courage, resourcefulness, far-sighted thinking and powers of experiment which were so notably the foundation for his distinguished and productive career.[6]

For similar reasons I have dwelt in detail on Professor Thomson's Philadelphia days, particularly on his work at Central High School. By the time he resigned from the school in 1880, he had unmistakably demonstrated his wide-ranging genius, and in his work there are to be found the seeds of his later achievements. Here it was, too, that he developed his lifelong interest in education and that fondness for teaching which led him throughout his life to cherish the title "Professor" above all others.

Professor Thomson resigned from Central High School to become "electrician" for the American Electric Company, a firm organized early in 1880 at New Britain, Conn., to control the Thomson-Houston patents. Two years later Thomson, at the suggestion of Charles A. Coffin of Lynn, Mass., formed the Thomson-Houston Company to take over the assets of the New Britain Company, and in 1883 the business was moved to Lynn. With Coffin assuming the burden of finance and management, Thomson was free to give undivided attention to research and technical development, and for the first time he was able to surround himself with competent assistants. The result of this happy arrangement was one of the most extraordinary

[4] "Pioneer Investigations on Dynamo Machines Fifty Years Ago," by Elihu Thomson. The *Journal of the Franklin Institute,* July, 1928.

[5] Unpublished notes of Professor Thomson in the files of J. A. McManus, General Electric Company, Lynn, Mass.

[6] Address of Dugald C. Jackson at the meeting in commemoration of the life and work of Elihu Thomson, February 16, 1939. In the files of the American Philosophical Society, Philadelphia.

records of technical achievement in the history of the electrical industry.

Founded in the period when Edison was demonstrating the commercial possibilities of electricity with his "Jumbo" dynamos, the company grew rapidly. In 1884 it employed 184 workers, but by 1892, when it was merged with its competitor, the Edison General Electric Company of Schenectady, the number had grown to 4,000.[7] The result of the merger was the General Electric Company, with Coffin as president and Rice, who had been manager of the Lynn plant, as vice-president and technical director. Not the least of Professor Thomson's contributions to the success of this great industrial organization was his demonstration of the value of industrial research.

Returning to the record of Professor Thomson's inventions, we find him in 1885 applying his magnetic blowout to lightning arresters. This fundamental method of breaking electric currents became the foundation for automatic circuit breakers and for controllers of electric cars and trains.

The basic idea of his lightning arrester derived from a knowledge and study of scientific phenomena involved in the discharge of electricity through gases. A transmission line, of course, has to be insulated from the earth by insulators adequate to prevent spark-over at the voltages used. If, however, the line is struck by lightning or an abnormally large electric surge passes through it, a spark may pass around the insulation, and it is a peculiarity of sparks through air that when once the insulation of the air is broken down by a spark there is no inherent limit to the amount of current which can flow. Thus these sparks frequently cause serious short circuits.

Professor Thomson's discovery consisted in placing the insulator between the poles of a magnet, with the result that the spark or arc which might be produced was acted on by electrical forces in such a way as to elongate it in the form of a bow which became more and more extended until it finally became so long that it went out.

Again in these early days and long before the importance of it was understood, Thomson had outlined the now universally used method of transmitting alternating current by transformers. He had written out a description of the system in 1878 and set up a working model at the Franklin Institute in 1879, but his patent application was not filed until 1885. After an unusually strenuous history in the Patent Office because of interferences with the work of Gaulard, Gibbs, Brush and others, the patent did not issue until 1902. When it did issue it covered every alternating current distribution system in the country, and it is not surprising, therefore, that the courts subsequently held the patent invalid.

In the further development of alternating current machinery he devised constant current transformers embodying the magnetic leakage shunt (1889), and a movable secondary (1894), which could be adjusted, in relation to a fixed primary, to give constant current output. Again, in the direction of increasing the power capacity of transformers, he obtained patents in 1890 covering the cooling of transformers by oil immersion and by air.

One of Professor Thomson's most fundamental discoveries was the principle of dynamical repulsion between a primary and secondary coil. This can be demonstrated by a variety of interesting lecture experiments, most of which were suggested and shown first by Professor Thomson himself. One of these experiments still serves as a spectacular demonstration for popular science lectures and for elementary classes in physics. A vertical wire coil is surrounded by a spool of wire through which a large current can be passed upon throwing a switch. A metal ring which slips easily over this core is dropped around it from above. Immediately upon closing the circuit this ring is shot up into the air by the repulsive action of the electric current produced in the ring and the primary current in the coil. This scientific observation was developed by Professor Thomson into an alternating current repulsion motor which is nothing more nor less than our present repulsion induction motor.

In the field of electrical measuring instruments, he invented the "inclined-coil" instrument (1895) and the Thomson integrating wattmeter (1889). It is this latter meter which is now almost universally used for measuring amounts of electric power used. In 1890 this instrument was exhibited in Paris and a prize of 10,000 francs for meters was divided between Thomson and Aron.

He next turned to the investigation of high-frequency phenomena. Already he had conceived the notion (1876), as I have mentioned, of tuning electric circuits, an operation fundamental to modern communication systems, and he had observed the propagation of electrical waves through space. In 1890 he patented a dynamo operating at frequencies 30 to 40 times greater than any previous machine. This led him to design high-frequency transformers. While working in this field he discovered (1893) a method of producing still higher frequency alternating current from a direct current arc, by shunting the arc with inductance and capacity, thus discovering the method which played such an important role in wireless transmission up until its virtual replacement by electronic tube devices. This interesting method of producing alternating currents was independently developed and

[7] "Professor Thomson and the Development of the Lynn Electrical Industry," by J. A. McManus, Tercentenary edition "Greater Lynn," June, 1929, Lynn Chamber of Commerce.

applied to wireless telegraphy by Poulsen, and is therefore generally known as the Poulsen arc.

Among his many other electrical inventions should be noted his resistance electric furnace patented in 1894, and a dynamo-static machine (1900) by which it was possible to obtain high-frequency discharges suitable for vacuum-tube apparatus.

In the summer of 1858, when 5 years of age, Thomson had seen Donati's comet and in 1867 he witnessed spectacular meteor showers. These early observations prompted his abiding interest in astronomy. In later years he published nearly a score of papers on astronomical subjects ranging from discussions of zodiacal light to solar eclipses.

Still other scientific byways of Professor Thomson's interest were the earth sciences. He published on "The Nature and Origin of Volcanic Heat," and in his last appearance before the American Academy of Arts and Sciences in 1933, he read a paper on "The Krakatau Outbreak." The eruption of this volcano in Java occurred when he was a small boy in Philadelphia, and had incited the curiosity which he always exhibited. He had watched for evidences, in the brilliant sunsets, of the volcanic ash in the upper atmosphere and had, I am informed, recorded his observations. At a much later date he hired as a research assistant a survivor of the catastrophe and induced him to record his personal observations of the event.

With all this intensive activity, Professor Thomson lived a rich family life. He was married on May 1, 1884, to Mary L., daughter of Charles Peck of New Britain, Conn., and of this union there were four sons, Stuart, Roland D., Malcolm and Donald T. In 1916 Mrs. Thomson died, and on January 4, 1923, he was married to Clarissa, daughter of Theodore F. Hovey of Boston.

Behind all his astonishingly varied interests, stood a man who had complete faith in the efficacy of the scientific method, and who in all his activities, vocational and avocational, was a shining exemplar of the scientific spirit. Observation and experimental inquiry were his chief reliances; he apparently did not resort to the mathematical or analytical methods that most scientists and engineers use who tackle problems as complex as he solved. He was not, like Steinmetz, a gifted mathematician; he seemingly did not need to employ mathematical analysis because his teeming mind leapt to correct conclusions without it.

His powers of observation he carried into every walk of life, and no one could be with him for ten minutes without being impressed and stimulated by his perception and by his wide-ranging knowledge of natural phenomena. He could best be described by saying that he was a brilliant natural philosopher who was held in equally high esteem by practical engineers and by academic scientists.

I have spoken of his devotion to education. His long association with the Massachusetts Institute of Technology affords a specific example. He became a lecturer in electrical engineering at this institution in 1894, and from then until his death he maintained with it the closest sort of relationship. He was elected a life member of the corporation in 1898, was acting president from 1920 to 1923, and for many years was a member of the executive committee of the corporation. He likewise served Harvard University as a lecturer and as a member of several of its visiting committees.

In other ways he never ceased to teach. His friend, Dr. Richard C. Maclaurin, President of the Massachusetts Institute of Technology from 1909 to 1920, observed:

> Throughout his life he has not only done great things himself but shown an intense desire to help all who are struggling earnestly with scientific problems. He has proved an inspiration to an ever-widening circle of engineers and others who have intrusted him with their secrets and sought his help in overcoming their difficulties. They have done this, knowing that they had only to ask in order to get the full benefit of his imagination and his power, and that they need have no misgivings that he would take any advantage of their confidence or any credit for their work, for he has no touch of selfishness.

From my own association with him I can validate Dr. Maclaurin's tribute. He combined in a most remarkable way the constructive power of the inventor, the intuition and imagination of the great scientist and the kindly balance of the ideal philosopher, teacher and friend. His life encompassed the development of the electrical industry, and he will long be remembered as one of those who brilliantly extended and applied the primary discoveries of Faraday and the other pioneers in the science of electricity.

He died on March 13, 1937, in his eighty-fourth year.