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THE SIGNIFICANCE OF PROFESSOR THOMSON'S WORK IN THE DEVELOPMENT OF ELECTRICAL ENGINEERING[1]

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ANY one with the misapprehension that engineering practise consists in following a set of fixed formulas, rules and specifications will do well to consider that electrical engineering and the art of useful application of electricity has developed almost entirely during the lifetime of Professor Elihu Thomson. The basic scientific discoveries of electromagnetic induction by Faraday and Henry had been made during the decade just preceding his birth, as had the first crude form of telegraph. But generators, motors, transformers, transmission lines, electric meters and regulators, electric lights, telephones, x-rays, electric discharges through high or partial vacuum, lightning protectors, converters, rectifiers, electrical insulators, wireless, radio and all the theory and practise of electrical networks are the product of science and invention since Thomson's birth on March 29, 1853. These things, and the economic problems associated with them, constitute the field of electrical engineering. Some of them Professor Thomson has himself invented, a majority of them owe much of their development to him, and there is scarcely a one on which he has not left his imprint in one way or another. Yet I suspect that he himself would be the first to maintain that we are as yet only at the threshold of the possibilities which are inherent in electricity for the services of man, and that no one would more stoutly advocate the continued endeavor to discover these possibilities and make them effective.

Granted this, it must nevertheless have been a particularly thrilling experience to be connected with the early engineering and industrial developments of electricity, in the early 1880's, when it first became evident that in electricity lay a mighty force whose

[1] Address given on the occasion of the eightieth birthday of Professor Elihu Thomson at the Massachusetts Institute of Technology, March 29, 1933.

potentialities were as yet but dimly imagined, yet which opened up in new directions, week by week, to the eager and talented young men, Edison, Thomson, Rice, Brush, Edgar, and the others.

Inspired by the possibilities which he had come to realize while experimenting with electricity as professor in the Boys' Central High School of Philadelphia, Professor Thomson and his colleague, Professor Houston, formed the Thomson-Houston Company in 1882, at the age of 29. With the able assistance of his pupil, Edwin W. Rice, he then began his long career of industrial and scientific research and its commercial development.

Perhaps Professor Thomson's first great contribution to electrical engineering was his invention in about 1879 of the three-coil dynamo with its automatic regulator and other features, which formed the basis of the first successful electric lighting system. This was put out by the Thomson-Houston Company in the early 1880's, and quickly found its place not only in this country but also in the leading countries of Europe. The machine was entirely automatic in its operation and so adjusted that it could maintain constant regulation in a system of many electric arcs, no difference how many of these arcs might be turned off or on. The need for such a regulator and its general nature were suggested to him by his earliest serious electrical studies, which were on the relation between the current and voltage in an electric arc, and which led him to the discovery that as the current increases the voltage falls—a relation which accounted for the instability of an arc, and pointed out characteristics which an arc dynamo should have.

It is interesting to note that this three-coil dynamo was a direct-current machine provided with a commutator, since in those days direct currents were more readily handled than were alternating currents and had certain advantages for arc-lighting purposes. However, exactly the same machine, simply with different connections, constitutes the three-phase generator which is so important in present-day electric power and was so represented by Professor Thomson in his original patent application. This is one of many cases in which Professor Thomson's ideas were years in advance of the world's readiness for their acceptance and utilization.

About two years later (1881) there was another great invention, that of a magnetically operated lightning arrester. Although this was designed for the particular purpose of protecting his arc-light systems from lightning, it was the invention of a fundamental method of breaking electric circuits, which has found very numerous applications, one of the most important of which was by Professor Thomson himself in the control of electric cars and trains.

The fundamental idea of this was again based upon an accurate 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 literally no 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. This principle is of just as great importance to-day as ever, and is the foundation of many recently improved schemes for the switching of very large currents.

Again in these very early days and long before the importance of it was realized, Thomson invented the now universally used method of transmitting electric power, stepping it down from a high tension with the aid of a local transformer for consumption. This was set up as a working model at the Franklin Institute in Philadelphia in 1879, a patent was applied for in 1885, and after an unusually strenuous history in the patent office, the fundamental patent for multiple-arc distribution systems with transformers was granted in 1902. During this same time and as an additional safety device for high voltage operation, Thomson patented the procedure of earthing the secondary coil of the transformer, a practise which has now become universal. In passing, I should note here, as an illustration of a notable characteristic of Professor Thomson, that this patent on his advice was dedicated by the General Electric Company to the public from a feeling that no patent or invention which has to do with public safety should in any way be restricted or made unavailable to the people.

In the further development of alternating-current machinery, he invented the constant-current transformer and the inductive regulator in which a movable secondary or primary coil could be adjusted automatically to give constant-current output. Again in the direction of increasing the power capacity of transformers, in 1887–89 he first proposed the use of oil for cooling and for insulation purposes in transformers, and furthermore called attention to the great and deleterious effect of moisture in the oil, an effect whose full significance students of insulators are only now beginning adequately to realize.

I pass now to two of the most important and characteristic of Professor Thomson's discoveries. The first of these is that process of electrical welding whereby the welded surfaces were fused and united by the heat developed on account of the resistance in the contact between them. This method of welding has come into enormous use in industry and the indications are that it will be even more used in the near future. As examples in widely different fields may be mentioned the welding of seamless metal tubing, the attachment of filaments and other electrodes in incandescent lamps and vacuum tubes, and the fastening together of most of the parts of the new Ford automobile. In the former of these applications, it may be interesting to know that a single manufacturer has manufactured in a single year enough bedstead tubing to reach around the earth.

Professor Thomson was not the first to utilize an arc in welding. The Demeritens patent, which was fundamental, was bought on advice of Professor Thomson by the Thomson Electric Welding Company in the early days, and, had arc welding developed within the life of the patent, that company would have controlled the arc as well as the electric resistance welding art.

Again, 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. For example, a vertical iron core was wound with a coil through which an alternating current could be passed. The core projected above the coil into a jar of water. Fitting loosely around the core was a second small coil, free to slip up and down the core in the water, and supporting by its terminals an incandescent lamp. When an alternating current was sent through the primary coil, a current was induced in the movable secondary coil which lighted the lamp and at the same time raised the coil, against the force of gravity, high up in the jar of water. This scientific observation was developed by Professor Thomson into an alternating current repulsion motor which is nothing more nor less than our ordinary induction motor, which is in almost universal use for small single-phase motors.

In connection with this discovery you will be interested in the following quotation from the *Electrical World* of May 28, 1887, commenting upon this work.

It is, as yet, too early to assign to its proper place and limit the part which the alternating current will take in the electric arts. It has started on its career with most rapid strides, and it now only remains to devise means for its accurate measurement, regulation and distribution. Certain it is that Professor Thomson's brilliant paper can not fail to act as a powerful stimulus to those whose attention is now absorbed in the direction indicated, and the fruits of which will soon be noted. We hope that at a later meeting of the Institute Professor Thomson will give to the world his practical results, which he has only hinted at in the present paper.

Professor Thomson was then 34 years of age. These practical results are now seen, for example, in probably a million induction motors in daily use.

During the years 1885–1895 Professor Thomson was busily engaged with the development of electric meters, especially recording watt meters, of which more than 4,000,000 are now in operation, and for this invention Professor Thomson was awarded the Paris Meter Prize of 1890 at a competition held after the exposition of 1889.

As early as 1890 and continued intensively for half a dozen years thereafter were a series of brilliant experiments on high-frequency alternating currents, paving the way for many of the developments in wireless and other high-frequency applications which are being so actively applied at the present time. He constructed the first high-frequency dynamo, operating at frequencies of 30 to 40 times as great as any previously designed, and in connection with experiments with this type of electric power, he designed also the first special high-frequency transformers. While working in this field, he discovered a method of producing still higher frequency alternating current from a direct-current arc, by shunting the arc with inductance and capacitance, thus discovering the method which played such an important rôle in wireless transmission up until its virtual replacement by electronic tube devices only within the past few years. This interesting method of producing alternating currents was actually applied to wireless telegraphy by Poulsen, and is therefore generally known as the Poulsen arc. Also in connection with these high-frequency investigations, he made the important discovery that the insulating power of oils at these high frequencies is very much greater than at the ordinary low commercial frequencies, if this insulating power is measured in terms of the path at which a spark will pass. Just one other item can be mentioned in connection with his high-frequency work, namely, the fact that he discovered and was the first to use the method of tuning electric circuits, which is, of course, absolutely fundamental to modern electrical communication systems. This was done very early in his career while he was still a professor at Boys' Central High School in Philadelphia, and was done in connection with experiments on wireless signaling which antedate the famous experiments of Hertz by about a dozen years, and, as far as I have been able to ascertain, constitute the first experiments on the propagation of electric waves and wireless signaling, with the sole exception of some experiments conducted still a dozen years previous to his by Joseph Henry in Princeton. These earlier experiments of Henry's were apparently never published.

Immediately upon the announcement of the discovery of Röntgen rays, Professor Thomson began a series of interesting experiments and valuable developments in connection with the x-ray art. The foundation for this work had been laid by previous experiments on electric discharge through gases at low pressures, and led to the first application of stereoscopic methods in Röntgenology only one year after the publication of the Röntgen rays themselves had been announced, and led also to various practical improvements in the design of x-ray tubes, as, for example, the double-focus x-ray tube and a cooled-target tube within less than a year after the discovery of Röntgen rays. In connection with these experiments Professor Thomson also took a lively interest in the physiological effects of x-rays, including x-ray burns, and in the laws governing diffusion of x-ray matter, subjects which have been developed on the one hand to exceedingly important applications in medical therapy, and on the other hand to give some of the most intimate knowledge which we possess of the internal constitution of matter, such as the arrangement of atoms in crystals and molecules, and the arrangement of electrons in atoms.

Things like these, and many more of them, constitute the tangible contributions of Professor Thomson to electrical engineering. His intangible contributions are less easy to talk about, but are none the less real and important. I can not close without mentioning a few of them.

Still quite tangible are his services to engineering education. From his earliest work as a teacher of science in the Boys' High School of Philadelphia, to his many years of service to the Massachusetts Institute of Technology as member of its corporation and executive committee, its acting president during a critical period, a frequent member of the visiting committee of its department of electrical engineering and non-resident professor in that department, he has been a continual inspiration and source of help to students and colleagues.

Rather less tangible is his influence in the many professoinal engineering and scientific bodies of which he is a member. Not only have his scholarly contributions been many and important, but he has consistently been an ideal connecting link between the practical and the theoretical, the commercial and the academic, by his example keeping them from being too narrow and maintaining a generous spirit of mutual appreciation and cooperation.

Still less tangible, but perhaps most important of all have been his inspiration to his thousands of business and research colleagues, his example of enthusiasm, perseverance, ingenuity, unselfishness, love of truth, generosity and broadmindedness.

As I have come to know it, the electrical engineering profession is on a remarkably high plane, both technically and also in general attitude. I believe its debt to men like Professor Thomson for making it a good profession in which to work is at least as important as its debt to him for so much of its basic technical development.

IN HONOR OF PROFESSOR ELIHU THOMSON[1]

By Dr. VANNEVAR BUSH

DEAN OF ENGINEERING AND VICE-PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THERE are many titles which I might use in presenting to you these greetings on the occasion of your birthday; but I feel sure that that of "Professor" is most welcome to you. It emphasizes an aspect of your accomplishments which I know is close to your heart. Great material changes have followed upon your scientific and engineering accomplishments, and these are visible to all of us in our daily lives. More subtle but none the less lasting is the influence of your many contacts with academic affairs. You have touched and moulded many institutions which are dedicated to the education of youth, and I bring you the felicitations of your colleagues everywhere.

Sixty-three years ago you were a professor in Philadelphia. We take great pride that you are still, and we hope will long be, professor of applied electricity at the Massachusetts Institute of Technology. Through these years your interest in collegiate affairs has been continuous. I need recite but a few instances. In 1890, just as I was born, and when you were thirty-seven, Yale recognized you as a master of arts. Tufts has the distinction of having conferred upon you your first doctorate, that of philosophy. Harvard made you doctor of science, and the University of Pennsyl-

[1] Address given at the dinner to mark the eightieth birthday of Professor Elihu Thomson, March 29, 1933.