BIRTH AND GROWTH OF WIRELESS

The Marvellous Valve

RIVAL OF MERLIN'S WAND

No. III.

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THIS article relates the history of the discoveries which led to the perfecting of the thermionic valve, which "is worthy to rank with Merlin's wand or Aladdin's lamp." This is an engrossingly interesting story.

WHILE great advances were being achieved in England under the direction of Marconi, progress was being made in various ways in other countries. The method of transferring the energy of electrical oscillation to the aerial by inductive coupling of a coil in the spark circuit to a juxtaposed coil in the line connecting the aerial to "earth," introduced by Braun, of Strasburg, has already been mentioned. Braun appears also to have been the first to show that the current passed more readily across a point of contact between a metal wire and certain crystalline substances when flowing in one direction than in the reverse, but the first recorded application of this effect to the rectification and detection of high-frequency electrical oscillations appears to be due to General Dunwoody, of the United States Army, in 1906. Thereafter, until the coming of the thermionic valve, the crystal detector rapidly supplanted the coherer, the magnetic detector of Rutherford and Marconi, and other forms of detector which had been invented.

Another highly important advance in the technique of transmission consisted in the substitution of "continuous-wave" (C.W.) types of oscillation-generator for the spark-generators, which could give at best only a regular succession of short trains of waves—one train for each spark that passed. In 1903 the Danish engineer, Valdemar Poulsen, succeeded in modifying the "singing arc" of the London electrical engineer, Duddell, in such a way as to produce by means of it powerful and continuously sustained oscillations at the rate, if desired, of several hundred thousands to the second.

The "Poulsen arc" rapidly rose to favor in high-power wireless installations, until in 1925 there were no fewer than seventy-eight stations equipped with arc-transmitters of 25 horsepower or more. In Germany and in America success was attained in the design and construction of alternating current dynamo machines which could generate oscillating currents of sufficient rapidity of alternation to serve for electric wave propagation; the powerful stations at Nauen in the former country and Long Island in the latter country were equipped with this type of transmitter.

Thomas Edison's Discovery

While all the above types of generator can serve admirably for the emission of the interrupted or abruptly modulated trains of wave which are required for the sending of the "dot and dash" signals of the Morse code, they are far from satisfactory when an attempt is made to superimpose upon the wave-train the far more complex and delicate gradations of form and intensity which are required for transmission of speech or music. Spark-generators with their broken series of wave-trains, are obviously unsuited for such a purpose, and although both Poulsen with his arc and Alexanderson with his alternator achieved a certain measure of success in radio telephony the difficulties of modulation and the impossibility of eliminating undesirable irregularities in the wave-train constitute very serious disadvantages, if not fatal objections, to the use of these generators for the transmission of speech, and still more of music.

It is then an essential condition for successful telephony by electric waves that the wave-train should be absolutely steady and unbroken except for the variations impressed upon it by the sound-vibrations to be transmitted. By what means can such a train of oscillations be produced?

The solution to this problem was to come from another and, at the date of its discovery, a little regarded quarter of the field of scientific investigation. In 1883 Thomas Edison, in making some experiments on the incandescent electric lamp which he had invented a few years before, noticed that a small metal plate attached to a wire sealed through the glass bulb, but insulated entirely from the white-hot carbon filament within, acquired, despite its insulation, a charge of negative electricity. This curious "Edison effect" lay unexplained and unapplied until further investigated by Professor (now Sir Ambrose) Fleming, of London.

The Fleming Valve

Fleming began his experiments on the "Edison effect" about the year 1887, and carried them on for about ten years. Although these experiments clearly established the fact that an electric current passed much more readily in one direction than another between a hot filament of carbon or metal and a cold metal plate contained in the same evacuated bulb, it was not until nearly ten years later that Fleming applied this instrument to the purpose of rectifying the oscillatory currents induced in a circuit by electric waves.

In the meantime the scientific researches of J. J. Thomson and his pupils at the Cavendish Laboratory had brought to light the existence and nature of "electrons," those minute particles of negative electricity which are constituents of every kind of material atom, and the nature of the "Edison effect" had been shown to consist in the spontaneous emission of electrons from the white-hot wire or filament, into the space surrounding it. These electrons can, then, act as "ions," or carriers of electricity from the hot wire to an adjacent plate or wire, and since the "ions" are produced by a purely thermal action, the word "thermionic" was used to describe the effect, and any rectifying device based upon it is termed a "thermionic valve."

The original "Fleming valve" of 1904, consisting of a cylinder of sheet metal surrounding the heated filament in an evacuated glass bulb, is identical in the essentials of construction and operation with the valves used to-day by the thousand for the purpose of rectifying high-tension alternating currents in order to obtain a high voltage continuous current supply for X-ray tubes and other purposes.

de Forest's Wonderful Discovery

Such valves are now made capable of rectifying voltages as high as 100,000 volts, or even higher. Their efficiency is, in fact, better the higher the voltage, for it is necessary that the vacuum be extremely good to avoid breakdown, and in such highly evacuated tubes there is a drop of voltage in the tube itself which at lower voltages involves an appreciable loss of power. For this reason it seems doubtful whether Fleming's two-electrode valve would ever have supplanted other forms of rectifier, such as the crystal, in which this voltage drop is practically absent. Certainly by allowing a small quantity of air, or better, some inactive gas, to remain in the bulb, this defect is largely reduced. But such "soft" valves have other limitations and defects.

It was the addition of the third electrode or "grid" intermediate between the other two which converted the valve into the marvellous instrument as we now have it. For the invention of the three-electrode valve, Dr. Lee de Forest, of New York, deserves well to stand in the ranks of the world's greatest inventors. For the addition of this third electrode, combined with a local battery to drive a stream of electrons from hot filament to plate through the intervening "grid" not merely enables the valve to function as an efficient converter of high frequency electrical oscillations into direct currents of proportional strength; it permits it also to function as a "relay," infinitely surpassing in delicacy of control and faithfulness of reproduction the finest mechanical relay yet constructed. The application of electrical impulses—whether due to the

excitation of currents in the aerial by electrical waves, or to any other cause —to the third electrode or grid causes a variation of the electron stream passing from filament to receiving plate or anode, and consequently delivered by the valve which may exceed a thousand times or more the power which controls it. And this magnification or amplification can as easily be repeated by using the output of the first valve to control a second.

The Thermionic Valve

But the de Forest valve (the inventor's own term for it, "audion," has not found permanent favor), can function in yet another way which excels in its importance for the art of radio communication even its great utility in the role of a "detector," or of an "amplifier."

In 1913 the Austrian wireless engineer, Alexander Meissner, discovered that by "coupling" a coil in the "plate" circuit of the valve with one in the "grid" circuit, self-sustained electrical oscillations could be produced in either circuit.

In the invariability of their strength and constancy of their frequency, in their freedom from admixture with irregular disturbances, and in the ease with which either strength or frequency could be controlled, this method of generating oscillations soon proved to be far superior to any other hitherto devised. Claim to independent or even prior discovery of a method of generating oscillations by means of a valve has been made by Lee de Forest and also by E. H. Armstrong, of New York. The first application of this new oscillator to the purposes of radio telephony appears, however, to have been made by Meissner —acting for the Gesellschaft fur Drahtlose Telegraphie—in June, 1913.

In its triple capacity as a generator of high-frequency electrical oscillations, as an amplifier of their strength, or as a rectifier for converting these oscillatory currents into unidirectional pulses capable of exciting a telephone diaphragm, the thermionic valve must certainly be reckoned among the most marvellous of all the tools which man, to aid the feeble powers which nature has bestowed on him, has yet devised.

Suitably connected in an electrical circuit with coils, condensers, and batteries, it can produce hour after hour or even day after day, an unbroken, unvarying train of electrical oscillations, the frequency of which may be varied from one or two to many millions per second, and the intensity of which can be controlled to accord faithfully with the tones of the voice or even with the almost infinite acoustical complexities of orchestral music. Transferred by a simple juxtaposition of coils of wire to an aerial those oscillations produce, in the space around, electrical waves of a frequency, intensity, and modulation in exact correspondence with those qualities in the parent oscillation which travel with the speed of light to the outermost corners of the earth, even to the very antipodes, there to excite in a frail wire hung aloft to receive their fleeting, faint caress the perfect, if almost infinitely attenuated, replica of the oscillations that produced them; finally, amplified ten-thousandfold in strength and purged of their oscillatory nature by the same marvellous instrumentality, these reproduced oscillations emerge to audibility as coded message, speech, or music.

Surely, the Fleming-de Forest "valve" is worthy to rank with Merlin's wand or Aladdin's lamp, even if these could be deemed other than bizarre inventions of human fantasy.

The fourth article of this series will appear to-morrow.