tunities for the inventor here are, therefore, enormous.

The electro-chemical branches are also very promising. At the present time a large portion of the copper product of the world is refined electrically, and practically all the aluminum which is now used very extensively in the arts is produced by electrical processes. There are growing up around Niagara Falls a great many works of this kind which already consume nearly 50,000 horsepower, and which will be increased when more power is provided.

Few people outside of the profession realize the amazing progress that has been made in this field of electro chemistry. And yet we are only at the beginning. The inventive genius is producing new processes almost every day that are revolutionizing results. Some of the experiments under way are almost fantastic, though they are being pursued by serious minded men. There is one concern, for example, at Niagara that is about to produse nitric acid out of air. The air is passed through an electric apparatus and its component parts, nitrogen and oxygen, which exist as a mere mechanical mixture, are caused to combine chemically. The gases thus produced are absorbed to form a very pure grade of nitric acid, at a low price. So far the process has not been established commercially, but there is said to be every prospect of success in the near future. Then we shall have the spectacle of producing, out of the atmosphere, one of the most valuable products in the world, for which there is an unlimited demand for fertilizing purposes. Besides such a process a gold mine would be a cheap and unimportant affair.

Hardly a day passes but some new electrical invention is not put out. These inventions vary in importance, some being small devices which are used incidentally in various arts, and others being radically new departures which revolutionize some industry, in which case their value may run up to a million dollars or more.

The possibility of generating electricity directly from coal has occupied the attention of many of the greatest inventors of the world, including Mr. Edison, but to the present time little or no progress has been made. We are still depending upon the boiler, steam engine and dynamo for nearly all our electric current, except in those favored places where nature provides water power, as, for example, at Niagara and in Switzerland. But most parts of the civilized world do not possess sufficient water power for their need. This is particularly true in England, where the water power is very insignificant. But even with water power the advantage is not great, as it costs nearly as much to deliver a current in Buffalo from Niagara as it does to produce it on the spot with a steam engine. What the whole electrical world is looking for is some direct process or apparatus in which coal may be introduced, and from which the electrical current will be generated directly. In other words, something like an electrical battery in which coal is used in the place of zinc. The person who solves this problem on a commercial basis will win greater fame than any inventor has ever known, and his reward in dollars should make him a Croesus if he has business talent.

The annual Pershing Rifle drill and spell-down will take place this afternoon in the armory. Owing to the muddy condition of the campus the usual inspection of the battalion by the governor and his staff will not be held.

Wireless Telegraphy and Hertz Waves

(*Continued from page 1*).

a hollow square as was formed by Napoleon's troops at Waterloo as defense against cavalry. Now conceive that such a square has been formed in the plain and that a wire has been passed nine or ten times around the square so that finally each grenadier holds in his hands nine turns. In this coil of wire is inserted a strong battery along with a rapid make and break device, called a vibrator. By means of an exactly similar square surrounded by wire in the same way, but provided with a telephone receiver, we may now receive messages across an intervening space equal to four times the diameter of either square. Indeed in 1898 Prof. S. P. Thompson, president of the English Institute of Electrical Engineers, an exceedingly practical man, expressed the opinion that the two systems just described are both feasible as a means of connection between England and America. He was at that time more doubtful about the Marconi system.

We now come to the Marconi system, and to understand it we must revert to early experiments, which have a bearing on the subject. Oersted, in 1820, discovered the deflection of the compass needle, while Arago and Davy observed in the same year the magnetizing properties of a helix. Both effects show clearly the fact that the electric current and magnetic force are essentially at right angles to each other. Perhaps this fact is responsible for the lack of definite mathematical expression of the interaction of the two forces prior to the work of Clerk Maxwell. The next discoveries involved were those of Michael Faraday, made between 1830 and 1835. This prince of experimenters discovered magneto-electric induction or the power which a magnetic field has to set up an electric current in a wire which is moving across it. He also discovered the differences in the behavior of various insulators, as glass, rubber, etc., when they are interposed between electrified bodies. This is due to what he called dielectric inductive capacity and has a strong bearing on Maxwell's electro magnetic theory of light, of which I shall soon speak. Finally Faraday believed that there must be some physical relation between light, electricity, and magnetism. He diligently sought such a relation and thereby discovered the rotation of the plane of polarized light when it is projected through a transparent medium under stress in a magnetic field.

Clerk Maxwell bears the same relation to science that Shakespeare bears to literature. Both are almost inconceivably great. Maxwell, basing his work on the experiments which I have enumerated, succeeded in combining the magnetic and electric forces in one mathematical expression, which at once completely accounts for them, both in a rational and consistent manner. His theory is really based upon the conception that electric energy in the potential state is resident in the dielectric or insulator surrounding a charged body, while the energy of an electric current is resident in the surrounding magnetic field.

The latter acts very much as if it were endowed with inertia; as though something in the magnetic field, called by Maxwell corpuscles, must be set in rotation like small flywheels before an electric current may be fully established. Some authorities refer, accordingly, to the energy of the magnetic field as being kinetic. Maxwell's theory fully accounts for the mode and result of the interchange of energy from the dielectric to the magnetic field and vice versa. When applied to light, Maxwell's electro-magnetic theory, as above developed, implied that this form of radiant energy is entirely electrical in its nature, being propagated in the same manner as an electric current or a magnetic attraction and at the same finite velocity, namely 185,000 miles per second. This electro-magnetic theory of light was confirmed by the fact that the dielectric inductive capacity, as measured by Faraday, for a given substance, was found to be the same as the refractive index of the substance, which is a necessary consequence of the theory.

As regards wireless telegraphy, the significant point in Maxwell's work was that it clearly implied the existence of electro-magnetic waves in wires or in space, differing in no essential from light waves except as to length. While light waves are the merest fraction of an inch, Maxwell showed that waves anywhere from a centimeter to a thousand miles in length were to be expected.

In the electrical engineering laboratory is a machine, an alternator, which produces 125 double vibrations in a second. This is slow compared with the vibrations used by Marconi. A circuit carrying current which fluctuates no more than 125 times per second will not project energy into space. As the rate of vibration increases in the electric circuit, a greater and greater proportion of its energy is radiated into space never to return. It might have been expected that if rapid enough vibration could have been produced in an electric circuit enough energy would be radiated to be appreciable at considerable distance. Working upon this hypothesis and in full command of the Maxwellian mathematics, a young German philosopher, Henry Hertz, in 1886 discovered the waves predicted by Maxwell, and which had been long sought for by experimentalists.

Let us proceed as did Hertz in his famous experiment. Here is an induction coil fed with current through a Wehnelt electrolytic interrupter. By the sound of the interrupter we know that the vibration is not very rapid since it gives forth only a noise and not a musical note. But these major sparks in unison with the Wehnelt are each composed of many to and fro impulses occurring at a rate measured in the tens of thousands per second. These are due to what we would call the natural vibrations of the coil, and were known before Hertz.

Now, a peculiar phenomenon occurred which gave the key whereby the unexplored region of short waves, i. e., from one half to several meters in length, was to be unlocked. Hertz, using a piece of wire bent like a letter "C," the extremities nearly touching, discovered that if one end of this wire were applied to one of the discharge rods of his induction coil, small subsidiary sparks would jump across between the ends of his "C" shaped piece, which he afterwards named "resonator." To his great mind this discovery implied that the electricity had been so suddenly applied to one end of the resonator that, although it traveled with the velocity of light, it did not have time to travel around the "C" and arrive at the other end, ere a spark had leaped across from the charged end to the one which had not yet arrived at the potential of the source. Here must be a rate of vibration far exceeding the tens of thousands per second above referred to. In fact later developments showed that the spark must be considered as a second time differentiated, giving rise to a vibration measured in hundreds of millions per second. It is this third degree of superimposed vibration that gives rise to the so called Hertz waves, the same which are the active agents in the Marconi system of signaling.

In view of what has been said about the seat of electric and magnetic energy, it should now be possible to explain that this very rapid vibration is caused by the exceedingly rapid transition back and forth, of the energy of the coil. First the energy is magnetic surrounding the rapidly flowing electricity of the spark. When the vibration in this direction ceases, much of the energy has been stored quiescent in the dielectric or air surrounding the discharge rods, only to flow back again an instant later into the magnetic field with the reverse spark. Now conceive that a part of these rapid magnetic impulses radiate in circles concentric with the spark, changing position only by dint of their ever expanding diameters, just as circles of water expand when a stone is cast. The radii of these magnetic whirls grow at a rate of 185,000 miles per second, and the impulses follow so rapidly one upon another that the distance between whirls, or the wave length, is ordinarily only a few meters in length.

Now Marconi employs a vertical wire attached to his induction coil. The electric forces vibrating up and down this wire set up a multitude of ever expanding horizontal whirls of magnetism, whose circumferences finally cut squarely across the vertical wire at the receiving station and induce electric currents therein at right angles to the direction of the magnetic force. In fact we may conceive that such electric forces are carried along with the magnetic whirl, stressing the ether at right angles to the plane of the whirl as it passes. Thus we have an electric wave coincident with the magnetic, their respective planes being at right angles to each other. Now it is this electric or vertical wave which corresponds to what we mean by a plane, polarized beam of light, although the horizonal or magnetic wave is always present. Hertz waves behave exactly like light waves with two exceptions. They do not affect the retina and they possess the power of penetrating non-metallic bodies. Waves of a few centimeters in length can penetrate only a limited quantity of earth or stone, but the long waves measured in miles seem to be able to pass through even hills and mountains, undiminished in strength. Using large cylindrical parabolic mirrors made of zinc, Hertz succeeded in demonstrating the laws of reflection, refraction, polarization, interference, etc., and showing their identity to those of light. Like light waves, the Hertz waves are cut off by metallic bodies even of great thinness. The refractive index for Hertz waves is similar in magnitude to that for ordinary light, and hence large lenses might be easily built of glass, pitch, or other similar material to condense or focus the effect from a distant spark upon any particular point. In fact in a system of wireless telegraphy there is no real reason why a multitude of transmitting sparks might not be singled out and identified at a given receiving station by the use of proper lenses, even as the stars are differentiated by a telescope.

PROF. GEORGE H. MORSE.