the rim of the wheel against the bottom of the clamps. Clamp *B* is first drawn away from clamp *A*, to its extreme position, and then the tire, which has been previously strung with a pair of wires, is loosely fitted into the channel rim, its two ends being held back by the clamps, but the wires projecting through their jaws.

The wire ends which project through the clamp, *A*, are gripped by its jaws, but the other ends projecting between the jaws of clamp *B* pass freely through clamp *A*, and are wound around the drum, *C*. A block is placed in each clamp between the wires to hold them in their proper positions. The block in clamp *A*, however, is thinned down at its upper end so that the wires which extend to the drum, *C*, will not be gripped when the jaws are closed. These wires are now wound up tightly on the drum, *C*, and secured by closing the jaws, *B*. To attain the necessary tension the tightening screw, *D*, is operated. A powerful pressure is thus brought to bear on clamp *B*, which stretches the wires to their utmost. This done, all superfluous wire is cut away, and the overlapping ends filed on a taper to make a smooth joint. Asbestos is then packed under the wires, and particularly against the clamps, so as to prevent the intense heat, necessary in brazing, from harming the rubber tire. The wires are now brazed together in the usual way, and our first and most important operation is completed.

The wire rings, it will be found, have been drawn so tight that the rubber cannot, with ordinary means, be drawn over the splice, and this brings us to the second operation, which is illustrated in Fig. 4. The wheel is supported by a vise, which grips the rim near one end of the rubber tire, and a clamp, *G*, is secured to the other end. A U-shaped lever, *J*, straddles the wheel rim and is hinged to the vise. Pivoted to each leg of the lever, *J*, near the vise, is a ratchet bar, *H*, which has notches along its lower edge. These ratchet bars are adapted to hook over pins on each side of the clamp, *G*. Now, by drawing back the lever, *J*, the end of the tire which is held by the clamp is drawn, little by little, up against the end secured in the vise. Any unevenness or bunching of the tire is then in a similar manner straightened out, after which the wheel is ready for service.

The process for tape-strung tires is the same except, of course, that no separating block is necessary in the clamps, *A* and *B*. Inserting the tape into the tires is, however, rather difficult, because the tape is sure to bind along its edges. It has been found necessary to attach a force pump at one end of the tire opening, which is operated while the tape is inserted from the other end. The air pressure inflates the opening and permits a freer passage for the tape.

Car tracks, and particularly their switches, cause most of the damage to carriage tires. A terrible wrenching strain is received when the vehicle is suddenly swung out of a car track. Sometimes the rubber is so badly torn that it is necessary to patch it with a section of new tire. This is easily done, as shown in Fig. 3, the new section, *E*, being inserted in the old tire, *F*, and all made secure by the retaining wires.

ELECTRICAL RESONANCE AND ITS RELATION TO SYNTONIC WIRELESS TELEGRAPHY—I.

BY A. FREDERICK COLLINS.

The recent transference of the Pupin electrical resonance patents to the Marconi Company has created more than a passing interest in the application of resonance principles to syntonic wireless telegraphy.

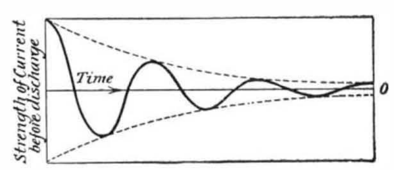
In wireless telegraphy practice it is well known that an electric circuit having definite values of inductance, capacity and resistance will respond to currents of high frequency set up in a circuit of the same dimensions.

This phenomenon is termed *electrical resonance*, taking its name from the similarity of the action produced and the means by which it is accomplished to the resonance in acoustics where the sound waves cause a sympathetic vibration in a suitable medium. As a familiar illustration of acoustic resonance, let two tuning forks of the same size, pitch and form be placed a given distance apart so that the waves set in motion by the vibrations of the first fork will impinge on the second, when a vibratory reaction will take place and it will then respond to the fundamental tone and a second train of waves will be emitted.

The co-efficients of an electric circuit are its inductance, its electro-static capacity and its resistance, and upon these three factors the size of the circuit depends. Inductance is the effect of a current flowing in a straight conductor or a coiled wire on itself; the inductance of a wire is virtually electric inertia, since a current does not start or stop instantly, but requires the element of time to do either. Capacity is the quantity of electricity which must be impressed upon a circuit in order to increase its potential, or raise its pressure to a given value. The capacity of an electric circuit may be compared to that of a gas tank, the quantity of gas the tank may contain depends on the pressure with which the gas is forced in as well as on the size of the vessel; likewise the higher the electromotive force or pressure of the current and the smaller the capacity of the circuit, the smaller the quantity of electricity required to charge it to a given potential. The resistance of the conductor is the reciprocal of the electrical conductivity, or the ratio between the electromotive force of a circuit and the current it carries forward. The resistance of a circuit may be taken to be the sum of the opposition offered to the flow of the current.

The effects of these co-efficients vary considerably according to the nature of the current employed in

FIG. 1.

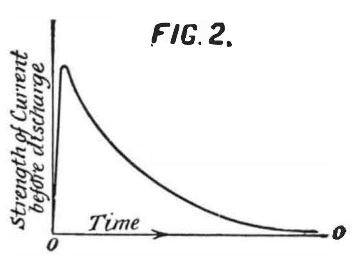


the circuit; thus the low-potential alternating currents employed for commercial purposes heat the conductor if it is of small cross-section, and radiate heat waves, in virtue of the resistance; but the inductance offers no great impedence to the current. Oppositely disposed, a current of high frequency will oscillate to and fro, with little regard to the resistance of the circuit, though the inertia of the current is greatly affected by the inductance, tending to slow down or damp the oscillations; these high frequency currents also possess the characteristic feature of dissipating nearly all their energy in the form of electro-magnetic waves.

ELECTRO-MAGNETIC THEORY.

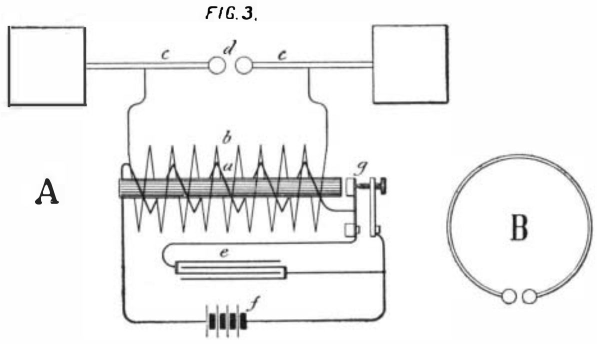
The electro-magnetic theory of light was invented by Michael Faraday, who was enabled, after a series of

FIG. 2.



laborious and difficult experiments, to demonstrate by physical methods that light, electricity and magnetism were allied to each other in a definite way. This he did by placing a cube of heavy glass of his own manufacture in the field of a powerful electro-magnet in such a way that when a pencil of light was passed through the glass the line of wave propagation was parallel to the lines of magnetic force.* Before the electro-magnet was excited an analyzer, similar to those used in polariscopes, was arranged to intercept all the waves of light. When the magnetic field was produced by the rotational current of electricity the light waves were twisted or turned through an angle sufficiently to permit them to filter through the analyzer. Proof was thus established that light and magnetism are closely related. Of electricity and magnetism the

FIG. 3.



same is equally true and more easily proven; for instance, when a current passes through a coil of wire it assumes all the characteristics of a magnet exhibiting the same curved lines of force, attraction for magnets of the opposite sign and repulsion for those of the same sign, and other phenomena of a like nature. This classical experiment and the researches of Faraday on the dielectric stresses in insulating mediums under electric strain led James Clerk-Maxwell to subsequently deduce by a delicate synthesis of Legrange's co-ordinate system† the mathematical evidence that undulatory motion in dielectrics is due to transverse vibrations of the ether or polarizations, and these polarizations are produced by changes of electric charges rapidly shearing the ether; the more rapid the movement of the electric charge, or period of oscillation, the greater will be the dissipation of energy in the development of the waves. The electric charge of an atom weighing one micromil in diameter may oscillate 434 trillion times per second propagating waves 271 ten-millionths of an inch in length, producing the sensation of red light, or the charge may vibrate with a frequency of 740 trillion times per second and send out a train of waves each measuring 165 ten-millionths of an inch in length, giving the color value of violet light; or the charge may vibrate between the limits of 271 and 740 trillion times per second, the varying wave lengths resulting in orange, yellow, green, blue or indigo light. Having determined that light-waves are electro-magnetic disturbances in the ether, caused by oscillating charges of electricity, it was not difficult to imagine a larger charge moving at a much slower rate in its reversals than atomic charges, and therefore emitting longer waves. Maxwell came to this conclusion, but to explain all the phenomena of wave emission and propagation by one ether he assumed that the velocity of transmission was in every case identical. By calculation and direct experiment this has been ascertained to be 186,500 miles per second.

Wave length as shown by a spectrum in Maxwell's time was not as extensive as it is to-day. Added to the visible spectrum discovered by Newton were band-showing waves shorter than the visible violet, and these were termed ultra-violet, and at the opposite end of the spectrum were band-indicating waves longer than the visible red; these waves were emitted by heat and were termed radiant heat or infra-red waves. That there were shorter waves than the ultra-violet and again others longer than the infra-red were postulated, but yet remained to be demonstrated.

ELECTRIC WAVES.

The present method for producing light waves by combustion is empirical and very wasteful, and the range of available wave lengths is limited by the ten-millionths of an inch. In 1888 the mathematically predicted electro-magnetic waves of Maxwell were observed by Hennrich Hertz, of Karlsruhe, Germany, who at the same time discovered the necessary apparatus for their production. The method for the production of the electric waves, employing the terminology of Hertz, is that of oscillating an electric charge of a mass instead of an atom. Prior to 1888 Prof. Fitzgerald described the conditions by which electric oscillations in masses could be set up; this was to "utilize the alternating currents surging in a circuit when an accumulator was discharged through a small resistance." This is the only method known where a longer wave than that produced by atomic vibration is desired, but Fitzgerald was unable to construct a physical apparatus to fulfill these requirements, yet the method as well as the apparatus is exceedingly simple, consisting of a Leyden jar charged by a frictional machine or electrophones and then discharged through a wire of small resistance by means of a spark-gap. When this action takes place the positive and negative charges of the Leyden jar or accumulator oscillate to and fro through the circuit formed by the wire and the spark in the air-gap, which has then a very small resistance, or mathematically expressed, the oscillations will take place if $R<\sqrt{\frac{4L}{K}}$, where *K* is the capacity of the circuit in Faraday, *R* the resistance in ohms and *L* the inductance in heneries. Fig. 1 shows in rectangular co-ordinates the curves described by an oscillatory discharge. The number of oscillations per second, or frequency, is determined by the equation

$$2\pi n = \sqrt{\frac{1}{KL} - \frac{R^2}{4L^2}}$$

If the resistance of the circuit is large there will be no oscillations, but the discharge will represent a smooth curve as in Fig. 2 or by the formula $R>\sqrt{\frac{4L}{K}}$

Thus the oscillations of a pint Leyden may number 18 million per second emitting waves 16 meters in length.

The Leyden jar arrangement gave a few oscillations at each discharge and then required recharging. Hertz greatly improved upon this by employing a Ruhmkorff coil and an oscillator system shown in Fig. 3, *A*, to keep up the potential. Here a direct current was passed through the primary of the inducting coil, *a*, and automatically interrupted; this set up low-frequency, but high-potential currents in the secondary coil, *b*, the terminals of which were connected to the oscillator, *c*. The oscillator system and the currents set up in it must be regarded as absolutely distinct from the secondary coil and the currents induced in it by the primary; the oscillator and secondary coil are connected, but the purpose of the secondary currents is to charge the oscillator system automatically, and the high-frequency, high-potential currents set up by the disruptive discharge cannot flow into the secondary coil, in virtue of its great inductance. The oscillator Hertz employed consisted of two brass balls, a centimeter in diameter and separated from each other by an air-gap a few millimeters in length; these spark-balls were attached to two brass rods ending in metal

* Dr. Bruce Jones. Life and Letters of Faraday.
† Maxwell's Electricity and Magnetism.

spheres 30 centimeters in diameter. When the two arms of the oscillator system, *c*, were charged to a sufficient potential the air-gap, *d*, was disrupted and a series of sparks filled the gap during the period of the oscillation of the electric charge. This set up in the surrounding medium stationary electric waves, also discovered by Hertz; these waves Hertz detected and measured by means of a circlet of wire having a minute spark-gap between its terminals, as shown in Fig. 3, *B*. The action of these waves in other circuits had been observed before Hertz, but the effects were attributed to electro-magnetic induction.

These are the fundamental principles underlying wireless telegraphy and upon which the whole art of syntonic methods is based; the working out of these laws constitutes the applied science of electrical resonance and in the following paper its relation to syntonic wireless telegraphy will be discussed.

(To be continued.)

THE BUILDING OF AMERICAN LOCOMOTIVES.—II.

In our issue of June 7 we pointed out that among the many great industries of America, none have more strongly marked national characteristics than the locomotive industry, and we traced the history of American locomotive building as illustrated by the growth of the American locomotive in the Baldwin Works from "Old Ironsides" of 1832 to No. 20,000, of 1902. The present article is devoted to a description of the great establishment in which an average of 1,500 locomotives a year is constructed, and from which they are shipped to almost every country in the world.

THE FOUNDRY.—The locomotive castings are made in a large foundry, measuring 80 x 400 feet. The most important castings are those of the cylinders and wheels, in addition to which there are the numerous less important fittings that enter into the make-up of a locomotive. The raw material consists of new pig iron and old stock, the latter including any good gray iron, such as old locomotive cylinders, grate bars, axle boxes, etc. The materials are melted down in three 50-ton cupolas, the output of which varies from 100 to 150 tons per day. The furnace mixture is in the proportions of 2,000 pounds of pig, 2,000 pounds of scrap, 1,750 pounds of coke and 50 pounds of marble. The foundry is served by seven jib cranes and two overhead traveling cranes.

THE CYLINDER SHOP.—The cylinder castings are cleaned and taken to a large shop devoted especially to the finishing of cylinders. One of the most interesting machines in this department is a special boring mill, designed for boring and facing the castings for the four-cylinder compound locomotives, of which this firm is making an ever-increasing number. Each casting consists of a high and low pressure cylinder, and a cylinder for the piston valve, together with half of the saddle. The mill is arranged so that the three cylinders may be simultaneously bored and faced, with a great gain of time and the certainty of accuracy of the finished work.

WHEEL-LATHE SHOP.—The wheel castings, which are cast in one piece, the rim being formed segmentally to allow for cooling strains, are taken to a special wheel-lathe shop, where the rims are turned, and the hubs are bored and faced. The wheels are forced onto the axles by hydraulic pressure and the tires are shrunk on. The axle ends are turned to an even size, and the hole in the wheel hub is bored less in diameter, by an allowance of three one-thousandths of an inch for each inch in the diameter of the axle. The two pieces are then put in a hydraulic press and the axle is thrust into the hub with a pressure which commences at 10 tons and finishes at as high as 125 tons. The tires are maintained on the rims by the initial tension set up when they are shrunk into place; but the tires of express engines are further secured by a retaining ring.

THE FORGE.—One of the most interesting departments is the forge, where raw material in the shape of wrought iron scrap, such as bolts, rivet-heads, etc., is piled up in small rectangular heap on boards, and raised to a melting heat in the furnace, from which it is taken out and hammered by steam hammers into slabs. The slabs are then put together in couples, heated and welded, the process being repeated until full-sized billets are formed measuring 8 x 8 inches by 3 feet in length. The object of this heating and reheating is to secure that thorough working of the material which is essential to the production of the highest grade of wrought iron and steel. A feature in the forge is the large battery of overhead boilers which is carried above the furnaces, the waste heat from the latter serving to raise sufficient steam to supply the whole forge shop.

CONNECTING-ROD ROOM.—A marked feature of this great establishment is the attention that has been paid to the question of labor-saving, both as regards the machines employed and the broader question of general shop management. Evidence of this is seen in the devoting of separate buildings, or of separate floors in buildings, as the case may be, to the construction of particular parts. Thus, we have already referred in this article to the wheel-lathe shop, the cylinder shop, etc. In fact, almost every detail of the locomotive of importance is machined and finished in its own particular room. One of the most interesting of these departments is the connecting rod room, where the rough forgings for the side and main rods are milled, planed, finished milled, and polished. The connecting rods are forged of mild steel. They are first centered in a lathe, then scribed out by templates, planed down to proper width; the ends milled to shape, and where they are of the new I-section, the recesses are worked out by milling the two ends, and planing out the intervening material. The brasses are forced in place by hydraulic pressure.

TENDERS.—The construction of the tenders is carried on in a separate building, one floor of which is devoted to the construction of the trucks and frames of the tenders; another floor to the laying out of the plates and the shearing and punching of the same, while on another floor the tenders are erected.

THE BOILER SHOP.—Unquestionably the boiler is today the portion of the locomotive which is receiving the most attention from locomotive designers. It is well understood that the efficiency of the locomotive depends upon the ability of the boiler to produce abundance of dry steam of the desired pressure when the engine is being worked to its fullest capacity. Steel plate is used exclusively in the Baldwin boilers, and it is received at the works in sheets of various thicknesses and sizes, some of which are as much as 20 feet long. The sheets are first marked out by standard gages, although in cases where they have to be flanged, the flanging is done previous to the template work. The rivet holes are then punched or drilled, as required by the specification; the holes of the boilers of foreign locomotives being invariably drilled, while American specifications usually call for punched holes. The boiler shop is replete with a large assortment of drills and punches, which are driven by several electric motors. Flanging as far as possible is done by hydraulic presses, one of which is shown in the accompanying illustrations. This machine is operated by two accumulators with a maximum capacity of 365 tons. The plate is heated in the furnace and the flanging is done between two suitable forms, one clamped to the lower, and the other to the upper table. Dome rings, smokeboxes, tube sheets, etc., are all formed up on this machine with great accuracy and speed. After flanging, the plates are returned to the boiler shop, where the edges are planed where necessary, or chipped with a chisel. The plates for the barrel are trimmed in a shearing press, their edges are planed, and they are then rolled to the proper curvature in the bending rolls. The boiler is now assembled for the riveting machines which, in these works, are operated by hydraulic power. The riveting dies are carried at the upper ends of two massive upright jaws which, in the larger machines, are tall enough to allow the boilers to be let down by overhead cranes, with the line of rivets between the jaws. The riveting commences at the top and is carried down to the bottom of the boiler by simply lifting the latter by the overhead traveler.

ERECTING SHOP.—The erecting shop is a fine building 160 feet wide and 337 feet long. It is divided longitudinally into two bays, each of which is served by two electric traveling cranes of 50 and 100 tons capacity. Three of our first page illustrations are taken in this shop, and they represent various stages in the erection of some of the extremely powerful freight engines which this firm is now turning out, the last of which, built for the Santa Fé Railroad, is considerably the heaviest locomotive in the world. Limitations of space forbid any detailed account of the method of erection, but briefly stated, it is as follows:

First the cylinders are set up at the height above the rails which they will occupy when the locomotive is completed, and the attached saddle is prepared for the setting of the smokebox. The engine frames are then erected and lined up. Next the complete boiler is lifted by one of the overhead cranes and placed in position, the boiler being bolted to the saddle. The tubes are then inserted and expanded. Then the driving wheels are put in place, or rather the boiler and frames are raised by the overhead cranes and lowered down upon the wheels, the journal boxes and the axles being guided in between the pedestals. At this point the engine has the appearance shown in the upper left-hand cut on the front page. Meanwhile the various boiler fittings have been put in place and connected up. The next step is the water test in which hydraulic pressure is applied at about 266 pounds to the square inch, the working pressure being 200 pounds to the square inch. Then the water is removed from the boiler and it is tested with steam at 10 per cent in excess of the working steam pressure. The connecting rods, link motion, etc., are assembled, the valves are set and the eccentrics keyed to the main axle. Meanwhile the boiler is being lagged, the same protection being placed over the cylinders. By this time the locomotive presents the appearance shown in the large cut at the bottom of the front page. The sheet iron jacketing is then placed over the boiler and cylinders. Then follows the engine test, the boiler being connected to a stationary steam plant and the engine run under steam. After the painting and various finishing touches the locomotive is ready for shipment.

THE TESTING ROOM.—Before closing, a word should be said with regard to the testing department, the work of which may be said to lie at the very foundation of the excellence which characterizes the output of this establishment. All material that enters the works is subjected to both a chemical and physical test. Every delivery of plates is numbered, as is also every plate in each boiler. When a set of plates is being shipped, say from a mill at Pittsburg, a piece is previously cut from every plate and expressed to the Baldwin testing department, where it is tested. The rejected test pieces are sent to the shipping clerk, and as the plate shipment comes in, the corresponding plate is returned to the makers. The boiler plate is of open hearth steel, of a tensile strength of 60,000 pounds to the square inch, and it must show an elongation of 25 per cent in 8 inches. By the careful system adopted of numbering every plate in every boiler and keeping a record of the test on each batch of plates, it is possible, in case of a boiler explosion, to refer to the test and obtain full data regarding the plate.

It is interesting to notice, in closing, the great increase in weight and cost of locomotives that has taken place during the past twelve years. In 1890 the average weight of a locomotive was 100,000 pounds, and its average cost $8,000. In 1902, the average weight is 150,000 pounds, and the average cost $12,000, the increase in cost having kept pace very closely with the increase in weight, and this in spite of the fact that labor and materials have risen very considerably in cost.

Imitation Meteorites.

Genuine meteorites are curiosities highly prized by museums and scientific collectors. Prof. St. Meunier, of the Natural History Museum of Berlin, paid as much as $5 per gramme for a meteorite. It is, therefore, conceivable that sharp practices should be resorted to by dealers in scientific curiosities. A band of meteorite counterfeiters was recently captured and considerable evidence obtained of very curious and ingenious methods for seducing the gullible collector. The members of this band were Corsicans. It was their practice to obtain natural rock resembling meteorites as closely as possible and then to burn them in order to produce the black crust which is one of the earmarks of every genuine meteorite. The pieces of rock were coated with lampblack, dissolved in molten sulphur. It seems, however, that this method was so crude that the deception was easily discovered, and the men were forthwith arrested.

Parisian Trees.

Paris is said to lead the world in the culture of city trees. The success of the French capital is due not so much to an admirable soil climate as to a well-organized system of caring for the trees.

In large nurseries young trees are grown and prepared for the Parisian streets. The culture of the soil is elaborate. From the very beginning the trees are pruned and staked to compel a straight growth. By frequent transplanting the roots become so hardened that they are enabled to withstand injury due to transportation. When a tree is sufficiently large, it is set out in the streets with the same care that was lavished upon it in the nursery. Often the cost of planting a single tree is $50. Whenever a storm destroys the city trees the nursery can be immediately drawn upon for another supply.

The Current Supplement.

The current SUPPLEMENT, No. 1390, opens with an interesting article on the Ruins of St. Mark's Campanile, giving some of the reasons of its fall. In a long and very complete article M. H. Dastre discusses the rôle of mosquitoes in the dissemination of diseases. Another article of interest, is that of Mr. Otis Mason, upon the Harpoon—Foremost Among Savage Inventions, the first paper of which appears in this issue. The subject of Electrolytic Production of Metals, with Special Reference to Copper and Nickel, is exhaustively treated by William Koehler, of Cleveland, Ohio. Among other articles of interest is one treating of Horned Lightning Arresters with Iron Framing; also a description of the Siemens and Halske Process for Purifying Drinking Water by Ozone. The usual Trade Notes and Recipes and Suggestions by United States Consuls are given.

Our attention has been called to a typographical error in the article on "A New Artificial Fuel," which appeared on page 92 of our issue of August 9. The statement is made that the calorific value of synthetical coal is represented by "1,300 degrees British thermal units." This should read "13,500 British thermal units."