60 amperes, so that a battery should allow a distance of 50 to 60 kilometers. The cells are placed in an iron-bound wood box, which is suspended by four chains, the points of suspension being supported upon springs. The battery has thus a double suspension, taking into account the springs of the cab. The box is prevented from swinging by a system of tie-rods.

The question of replacing the accumulator boxes in the cabs as they come in from service is an important one, as there should be no loss of time in changing the boxes. The cab, as it comes in with its exhausted battery, is brought under the gallery and rolled upon an inclined track. The battery is thus at a considerable height from the ground, and this permits the truck to be rolled under it upon a track arranged for the purpose. Below the cab is a hydraulic elevator, worked by a lever near by, which lifts the truck to the height of the battery; the latter is thus raised, as this permits the uncoupling of the suspension chain and tie rods. The latter is then lowered with its truck to the level of the rails and rolled into the charging house; a fresh battery, also upon its truck, is brought out and put in place by reversing the operation. In this manner the driver is not obliged to leave his seat while the battery is being replaced. During this time the motor is examined and put in order by a lid in the rear of the cab, or by removing the interior cushions of the cab and opening the seat. At present six of the inclined tracks or elevators have been installed.

DR. PUPIN'S IMPROVEMENTS IN LONG-DISTANCE TELEPHONY.

BY HERBERT T. WADE.

Soon after the laying of the first Atlantic cable, nearly fifty years ago, Sir William Thomson prophesied that it would not be possible to exceed a certain rate of speed in the transmission of signals, on account of the so-called capacity of the cable. This prophesy has held good, for notwithstanding multiplex and mechanical systems of telegraphy on land, the submarine cables are operated at an avarage speed of but twenty-five words a minute. The use of a submarine cable in telephony over a greater distance than twenty-seven miles in length (Dover-Calais) is not supposed to be practicable, and consequently telephonic communication is not available where a large body of water must be crossed. In telephone circuits where aerial wires are employed, there are also limitations, and yet long-distance telephony on such a scale as is desired, from New York to New Orleans, or San Francisco for example, has not been attained and is admitted by telephone engineers to be next to impossible.

After a series of experiments performed at the laboratory for electro-mechanics at Columbia University, Prof. M. I. Pupin has ascertained that with cables and air line conductors constructed according to a method thus far employed in the construction of long distance electrical conductors, which involves a somewhat radical but nevertheless a very simple departure from the methods, the efficiency of transmission of electrical energy is greatly increased, and that a number of the difficulties just enumerated may be readily overcome. The method may be stated broadly to consist in employing what Prof. Pupin calls non-uniform conductors in place of ordinary uniform conductors. In the course of his experiments he has made use of such conductors for long-distance telephony, and the researches in his laboratory have been marked with great success.

Electrical energy when sent over a conductor of such length as is used in long-distance telegraphy or telephony is transmitted in the form of electrical waves. The transmission of the energy under such conditions can hardly be called direct for it is first stored up in the medium surrounding the transmission line and from here it is then transferred to the receiving apparatus. If a periodic current is impressed on the circuit by the transmitting generator, we have periodic variations of current and potential along the transmission wire.

In the study of electrical waves it is found that the amplitude of the wave diminishes as the energy is propagated from the source. In short, a weakening of the current is caused which is styled attenuation, and for the constant of attenuation there is a mathematical expression in which the inductance, resistance, and capacity of the conductor, and the frequency speed figure. The loss of energy is due to the imperfect conductivity of the wire, and it is regulated by the inductance and capacity in the circuit. The most important feature of this regulation is the following: If a conductor has a high inductance, a given quantity of

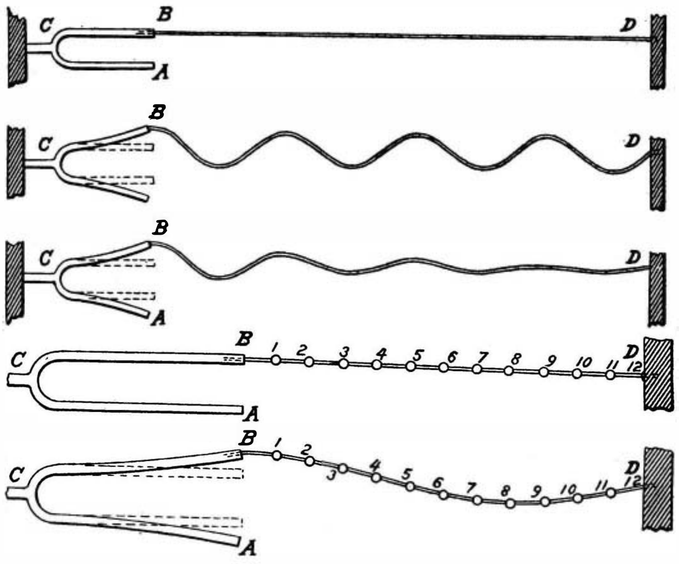


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.

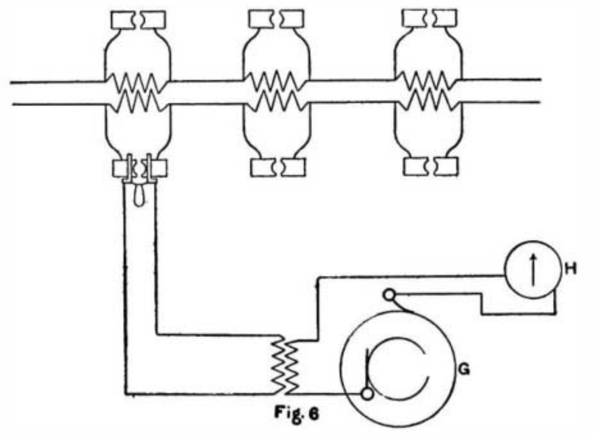


Fig. 6

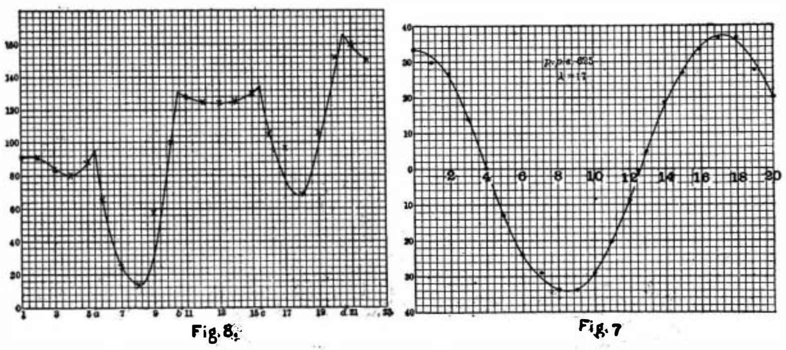


Fig. 8. Fig. 7

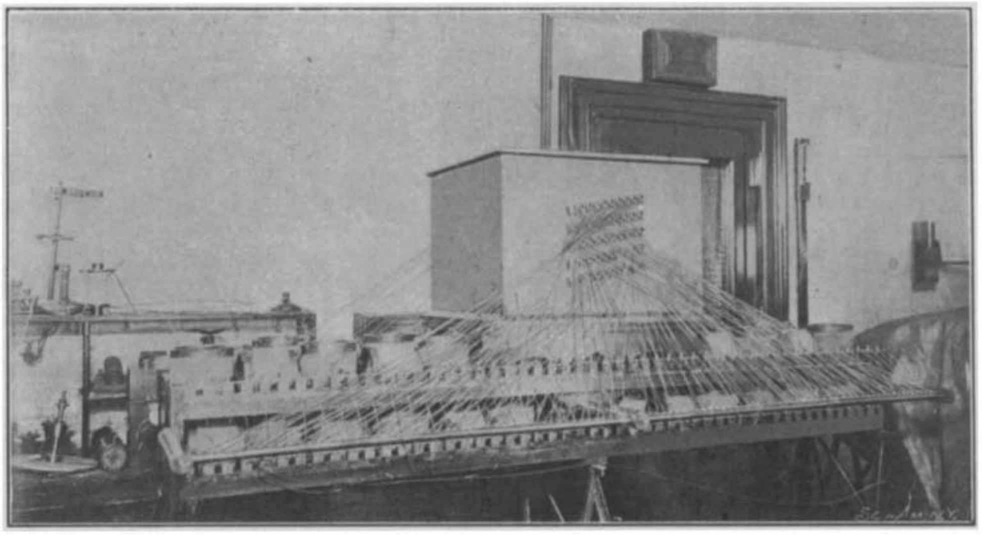
PUPIN'S INVESTIGATION OF CABLE TELEPHONY.

energy will be transmitted with less loss than over a conductor with a smaller amount of inductance. This fact was known to Oliver Heaviside, the mathematical physicist of England, and while his theory demonstrated the superiority of a wave conductor of high inductance, it did not indicate a way in which such a conductor could be constructed. The mere introduction into the circuit of a coil or coils has been tried without success, as there was no underlying mathematical theory to govern the experiments.

Prof. Pupin, however, has developed such a theory, which serves to explain the problem, and its main features are well shown in a mechanical illustration in which the same elements are present as are found in the question of the transmission of electrical waves. To one prong of a tuning fork rigidly fixed at C is fastened a cord whose other end is attached to some firm object as D, shown in the illustration (Fig. 1). Let the fork be set into vibration and a wave motion results, which, if the resistances due to friction are negligible, will take the form of stationary waves, as shown in Fig. 2. But assuming that the frictional resistances are not sufficiently small to be neglected, then the direct and reflected waves will not be equal, and instead of stationary waves there will be waves where the amplitude of the particles at the greatest distance from the tuning fork will be less than that nearer the source of motion, as shown in Fig. 3, the energy being dissipated by the frictional resistances in its progress along the cord. This weakening or attenuation, however, will be diminished if a string of greater density is employed, since a larger mass requires a smaller velocity in order to store up a given amount of kinetic energy, and a smaller velocity occasions a smaller frictional loss. Now let a weight, such as a ball of wax, be attached to the vibrating cord at its middle point so as to increase its mass. This weight will serve to occasion reflections, and there will be far less energy transmitted to the extremity of the string than before. Then, if the mass of wax be subdivided, and put at regular intervals, as shown in the diagram (Fig. 4), the efficiency will be increased. The further we proceed in this subdivision the higher will be the efficiency of transmission, but a point will be soon reached beyond which it is not possible to secure an appreciable improvement by further subdivision.

This point is where the cord thus loaded vibrates very nearly like a uniform cord of the same mass, tension and frictional resistance, as we may see by reference to Fig. 5. Therefore, to secure an increase in the efficiency of transmission over a cord thus loaded, we must properly subdivide the load and the distances, or otherwise the effects of reflection will destroy the benefits derived from the increased mass. In the experiments with the cord it was found impossible to load the cord in such a way as to make it equivalent to a uniform cord for all wave lengths, but if the load was distributed so that it satisfied a given wave length, it also answered for all longer wave lengths. The mathematical theory and law for the vibration of a cord under such conditions is exactly the same as that governing the distribution of the electric current over a wave conductor under the influence of similar forces, kinetic or mass reaction, tensional reaction and resistance reaction in the case of the cord being paralleled by electro-kinetic reaction, capacity reaction and ohmic resistance reaction in the case of the wave conductor. Therefore, it will be understood that if inductance coils are introduced along the wave conductor at periodically recurring intervals, the efficiency of the transmission of electrical energy is increased. Prof. Pupin's conclusion is that a non-uniform conductor is as nearly equivalent to its correspondingly uniform conductor as $\sin \frac{\varphi}{2}$ is to $\frac{\varphi}{2}$, where φ is the angular distance between the inductance points of inductance sources and the angular distance to 2π corresponds with the wave length. Here the value φ is inversely proportional to the wave length, so that for a given distance between the reactance points the degree of equivalence diminishes as the wave length diminishes. If the wave conducted be of complex nature, such as is met with in telephony where the overtones of the voice are present, then, if the approximation suffices for the highest essential frequency, the conditions will be even more favorable for the lower notes.

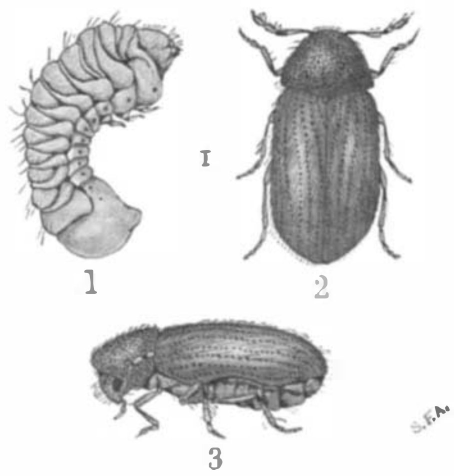
From theory to experiment was the next step in this investigation, and the study of these electrical waves was undertaken while they were passing over wave conductors. The experimental proof consisted in demonstrating that non-uniform conductors of the description just given will show the same wave-length and the same attenuation for a certain frequency and for all lower frequencies as a uniform conductor of the same inductance, resistance and capacity. The wave-length is of course conditioned by the frequency, and in the construction of the apparatus the periods used in long distance telephony were selected The conductor selected was the counterpart of a cable 250 miles in length, having the equivalent resistance and capacity. To construct such a cable was a task of much labor and



Arrangement of 250 miles of artificial line, with inductance coils at one-mile intervals, and telephonic instruments at either end.

Fig. 9.—EXPERIMENTAL CABLE WITH INDUCTANCE COILS.

three cables were made and experimented with, before the final form was reached which approaches very nearly the conditions existing in a submarine cable. This was formed of thin strips of tin-foil laid on sheets of paraffined paper and carefully connected, their length being sufficient to afford considerable resistance, while the capacity was regulated by the thickness of the insulating material. The strips were then connected in sections, each being equivalent to one mile of cable with a resistance of 9 ohms and a capacity of ·074 microfarads, and were arranged in



THE STORE-ROOM BEETLE.

1. Larva. 2. Beetle (dorsal view). 3. Beetle (side view).

groups of fifty, one such group being contained in the heavy case shown in the center of the illustration, Fig. 9. Having a cable where there is resistance and capacity, it is possible to demonstrate experimentally the vigorous attenuation of the current and to study the propagation of the electrical waves. This attenuation, as has been said, is remedied by the insertion of inductance coils into the circuit, and the illustration and diagram show the method of adding such coils. The wires from the various sections of the cable are connected with brass plates placed on a long wooden strip and by means of plugs and binding posts the circuit can be regulated. At the gap between any two successive sections of the cable a coil or coils containing inductance can be added, and by merely inserting a plug can be cut out of the circuit. Using a small alternator, and circuits with suitable inductance and capacity, to impress a simple harmonic electromotive force the waves were investigated. The alternator was so constructed as to give currents of different frequencies and thus produce the circuit waves of different length. Then with a slide contact, *G*, and galvanometer, *H*, arranged as shown in Fig. 6, it was possible to assertain the condition of the current at any point along the line. In this way observations were made and curves plotted showing the maximum and minimum amount of current and the length of the wave passing along the conductor. Such a curve is shown in Fig. 7, the numbers along the horizontal line in the middle representing the distance from the middle point of the cable, and the dots the current at various distances from this point.

Connecting these points we have a close approximation to an attenuated sine curve as required by the mathematical theory. In this case the wave length is 17 miles and the frequency 625 periods per second. Contrast this with the following illustration where the inductance is not properly placed in the circuit, and the result shows a remarkable attenuation and reflection of the waves. Leaving the exact mathematical considerations out of the question it may be stated if the induction coils are placed at intervals about one-sixteenth of the wave length the non-uniform conductor will be like a uniform conductor to within two-thirds of one per cent. If this is done the attenuation is made very small, comparatively speaking, and the electrical energy is transmitted with but slight dissipation. A numerical example will illustrate this more clearly. If the cable is employed with the inductance coils placed properly, then two and one-half per cent of the current generated at the transmitting end reaches the receiving end of the cable. But if the coils are cut out and the cable used in the ordinary way, then only one two hundred and fifty thousandth part of the current sent in at the transmitting end reaches the receiving end. In other words the insertion of the coils enables the cable to transmit 6,000 times as much current.

The first application of the results of this investigation has been to long-distance cable telephony. The cable being employed as before with the inductance coils at intervals of one mile, and at either end of the line two sets of ordinary telephonic instruments. Over this line of 250 miles of cable one can carry on a conversation distinctly, the fact seeming the more remarkable when it is realized that about 40 miles is the present limit for cable telephony and that the longest cables in the New York subways are 15 miles in length. These experiments from a purely scientific point of view demonstrate the feasibility of trans-Atlantic telephony.

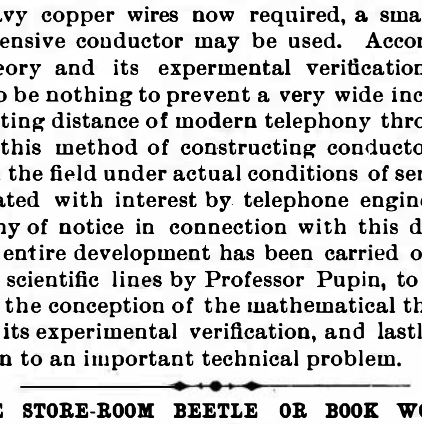
It is, however, in regard to its applicability to telegraphy, that its advantages for marine work must be especially considered, where, as soon as the speed is increased the attenuation of the waves occurs and a limit is very early set upon the rate of operation. With the attenuation taken care of by inductance coils added at specified distances along the cable, the current would be transmitted with small loss to its destination and not only would the ordinary speed of operation be increased, but by the use of methods similar to those employed on land for rapid telegraphy the efficiency would be made many times greater. The inductance coils could be added to the conductor at certain distances and placed within the sheathing at small expense in comparison with the cost of the cable, and being made about one inch in diameter and six inches in length would create no particular difficulty either in the manufacture or in the laying of the cable.

The earliest application of this method will doubtless be to aerial conductors to increase the present limits of long-distance telephony now placed at St. Louis from New York. The inductance coils at slight cost can be attached to the cross arms of the poles and instead of the heavy copper wires now required, a smaller and less expensive conductor may be used. According to the theory and its expermental verification, there seems to be nothing to prevent a very wide increase in the limiting distance of modern telephony through the use of this method of constructing conductors, and trials in the field under actual conditions of service are anticipated with interest by telephone engineers. It is worthy of notice in connection with this discovery that its entire development has been carried on along strictly scientific lines by Professor Pupin, to him being due the conception of the mathematical theory involved, its experimental verification, and lastly its application to an important technical problem.

THE STORE-ROOM BEETLE OR BOOK WORM.

BY S. FRANK AARON.

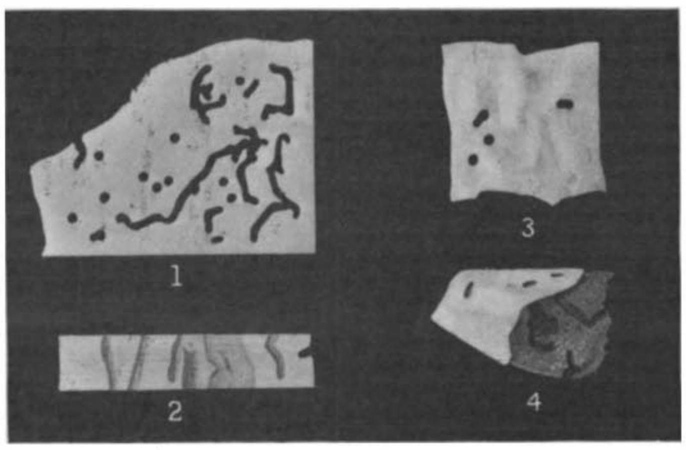
The subject of the present paper, the "store-room" or drug store beetle, is quite cosmopolitan, being



WORK OF STORE-ROOM BEETLES.

1. Cork of bottle of destroyed silk worms. 2. Perforated oil cake.

found in the torrid as well as temperate regions of both hemispheres. It is by no means confined to drug stores, but has been given that name because it is frequently found in materials and products stored and sold by the druggist. While it attacks many animal substances, there is hardly any limit to the number of vegetable materials in which it works. Remarkable



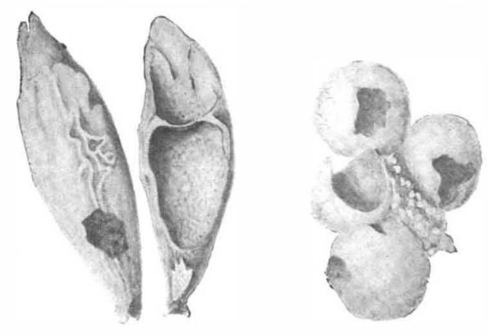
WORK OF STORE-ROOM BEETLES.

1. Paper bored by larvæ and beetles. 2. Section of book bored. 3. Tinfoil bored by beetles. 4. Pieces of chocolate covered by tinfoil, showing borings.

instances of its voracity and destructiveness are on record. The writer received from Japan ten bottles of silk worms that had been preserved in alcohol. The alcohol had evaporated from nine of the bottles, and the corks in each had been tunneled through and through and the silk worms turned to dust by these beetles. If the shrunken corks permitted the alcohol to evaporate, they would also allow the odor of the dried insects to reach the outside air, and thus the beetles were attracted.

A still more amazing instance follows. Several pounds of chocolate were received, each cake wrapped tightly in tin-foil. In nearly every package the tinfoil had been extensively perforated by these beetles, the chocolate was riddled, and much of it pulverized. Of course the odor of the chocolate could not escape directly through the foil, but must find an outlet through its folds. It was noticed that but few beetles were found in the cakes in proportion to the number that must have wrought the damage, and that the edges of the holes in the tin-foil were turned outward more than inward, suggesting the idea that most of the beetles had entered between the folds and had emerged directly through the tin. True, the metal is exceedingly thin, yet it must present a serious obstacle to a tiny insect of not more than six or eight times its thickness.

A set of six books in paper binding was received from Brazil, including three different kinds and colors



1 2

WORK OF STORE-ROOM BEETLE.

1. Barley grains entered and the interior eaten. 2. Sorghum seed bored into and destroyed.

of paper. These were bored through and through, the covers, pages of text, and plates being alike attacked; in some places the beetles working edgewise or diagonally through the leaves and excavating good-sized holes. In all cases the print was entirely avoided, only the margins and the parts about the pasted or glued backs receiving the injury.

Herbarium specimens of plants, seemingly without reference to species or condition, are subject to attack by these beetles. In such cases they not only perforate and eat away the dried plants, but also the paper upon which the plants are mounted. A sample is before me in which the one-time presence of the plant is indicated only by the dusty outline on the paper, which is bored through in many places. They are said also to attack manuscripts, drawings and gun-wadding.

No insect of the household or store room is as generally injurious as the drug store beetle. Such pests as the cockroach, the red ant, the rice weevil, and the woolen moth may be more in evidence, but their scope is far more limited and their ravages are more readily checked. The drug store beetle is the smallest of them all, but it makes up in its enormous numbers what it lacks in size. Its omniverous appetite is strikingly shown by another test. I recently reared several generations of these beetles in a small jar of ground pepper. They flourished there in the best of health, and they increased in numbers until finally the jar contained all beetles and scarcely a remnant of pepper dust.

To the scientist this beetle is known as Sitodrepa Panacea, a name given because the insect was first found in dried bread. It belongs to the family Ptinidæ. It is of a reddish brown color and varies in length from one-twentieth to one-tenth of an inch. The head is situated beneath the pro-thorax, the legs are slender, the body compact and rounded, and the motions rather slow. The larva is whitish yellow with black jaws, the pupa whitish, and the pupa case or cocoon is formed out of the dust of the larval borings. In an equable summer-like temperature the transformation lasts about eight or ten weeks, and in heated buildings there may be four or five broods annually.

The Current Supplement.

The current SUPPLEMENT, No. 1274, is an unusually interesting number. The leading article is devoted to the "Manufacture of Candles" and is accompanied by fifteen engravings. "The Murnau-Oberammergau Railroad" describes the new road leading to the scene of the Passion Play, and the play itself is also described. "The Art of the Paris Exposition and Some of its Buildings" is an elaborately illustrated article.

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