

to 4.1 deg., thus showing that the air current in the course of the day had altered its direction, at a time when the temperature of the outside air was higher than that of the inside air. The prevalence of diurnal variations in the interior of the cave commences definitely on the 26th of June, beginning from which date the outside temperature is higher. Special experiments and comparisons with air pressure records show

that this constancy or variability of the temperature in the cave is independent of the pressure of the outside air.

This "breathing well" thus has a draft comparable to that of a chimney, and no doubt communicates with the outside air through other deeper apertures. In order, however, that the air traversing a cave may assume a very constant temperature, as observed

throughout the winter, the cave should be very spacious. The constant temperature referred to is somewhat higher than the annual average of the air temperature at the summit of the Puy de Dôme, which from 1879 to 1906 has been 3.9 deg. C. The inside temperature thus corresponds to an average annual temperature in an air layer situated somewhat below the summit.

NOTES ON TUNING IN WIRELESS TELEGRAPHY.*

A BRIEF ACCOUNT OF RECENT METHODS.

BY SIR OLIVER LODGE.

I SHALL assume that the principles of tuning are known; it is not to be supposed that the application of these principles requires the arc. Sufficient tuning for all practical purposes can be obtained by using the right kind of spark. It is possible to acquire too long a train of waves, in which case the latter half of the train will undo what the former half has begun, in analogy with beats. Thirty or forty swings can be easily got by a spark, and that is enough for practical requirements.

A non-tuned station puts all the energy into a single snap, so as to produce a single discontinuous pulse calculated to affect every kind of station within the range of its power. For a tuned station this sudden snappy spark is to be avoided. The ideal arrangement is a spark of a sufficient number of alternations of approximately equal strength; no one of which is sufficient to operate, but such that the accumulated influence of all of them is powerful. Instead, therefore, of the clear polished metal knobs in fresh or compressed air, which are suitable for a snappy spark, a tuned station may employ a series of points inclosed in ionized air, so as to maintain conduction as long as possible. The maintenance is also assisted by using an alternator with a curve of the right shape—not a sine curve, but a high-shouldered curve (see Fig. 1)—so as to keep up the stimulating potential for a sufficient time. The spark passes when the potential corresponds to the point *a*, and a number of oscillations of nearly equal intensity are made between *a* and *b*.

But attention to the spark alone is not sufficient; it is necessary to eliminate the influence of the earth. For the snappy or non-tuned emission, such as was employed by Mr. Marconi for great distances, it is convenient to use an elevated wire on the one hand, and the earth on the other; but for a tuned station this is not appropriate. A tuned station requires two capacity areas above the earth. These capacity areas are usually horizontal frames (see Fig. 2) of shapes devised by Dr. Alexander Muirhead, who has found that there is a best position for the lower aerial, such that the capacity is a minimum. If the lower aerial be too much raised, the radiating power is diminished; if it be lowered, the train of waves is shortened, until when it is allowed to touch the earth—still more if it is connected with the earth—there is hardly any train of waves at all, and the discharge is almost dead-beat.

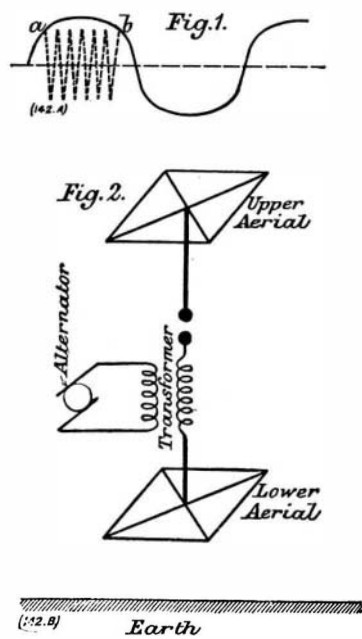
There is a great advantage in the getting rid of earth contacts, inasmuch as variations of moisture and uncertainties of the soil do not enter in to confuse the problem and throw the tuning out. But even if the earth remained constant, it would be deleterious; it seems by its resistance to damp out the vibrations and shorten the train of waves, in so far as it is allowed to exert any influence.

To receive a message from a distant tuned station, the first thing is to tune up accurately the receiver. This can be done by a Duddell radio-micrometer, which measures the received energy satisfactorily, although it is very small. Tuning is altered until the reading on this micrometer rises to a high value, then the receiving apparatus is purposely made unsensitive, so that the coherer will only respond to this high value; in other words, to the top of the curve. The message can then be received from the desired station. If the receiving apparatus were left sensitive, it would be affected violently by the desired station, but it would pick up a number of disturbances from other stations. By working at the top of the curve, it feels the desired station alone.

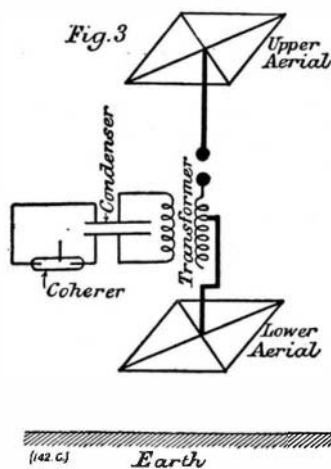
Tuning at the Sending End.—In order to economize power, it is desirable to have every part tuned. The aerials connected through the secondary of a peculiarly-made Ruhmkorff coil constitute one oscillating system of a low frequency, to correspond with an ordinary commercial alternator which excites them. When the swing is worked up, they burst through the spark-gap, short-circuiting out the Ruhmkorff, and giving excessively rapid oscillations, which are the ones transmitted. These are picked up by the receiving station, and transferred at constant frequency into a closed condenser-circuit (see Fig. 3), which, when its swings reach a maximum, overflow into the coherer. This is

called the "overflow method," and was described by me in 1889 and 1891.

Theoretical calculations show that the energy received, compared with the energy radiated, depends on the cube of the linear dimensions of emitter and receiver, if they are alike, and likewise on the cube of the distance between them. Measurements made with the radio-micrometer confirm this estimate ap-



proximately, the value in one series of experiments being 10^{-9} . Although this is a small fraction, the accuracy of the tuning is such that messages are sent between Burma and the Andaman Islands—a distance of about 300 miles—with less than a horse-power. To get such a result, precautions must be taken to avoid damping out the oscillations, not only by elevation of the lower aerial above the earth, but by using appropriate condensers for these excessively high frequencies. To this end the wires used are finely subdivided in insulated strands, and consist of a great cable or bundle of thinly insulated No. 40 wires, and the various self-



inductions, and other arrangements for effecting tuning, are similarly wound. The tuning capacities are also arranged so as to be continuously adjustable without pegs or discontinuities, and every kind of broken or uncertain contact is scrupulously avoided.

SOME PROPERTIES OF ELECTRONS.*

INVESTIGATIONS concerning the nature of the process of electric conduction in metals have led to the conclusion that in the metals are to be found molecules and atoms of the metallic element, positive ions and free electrons. The molecules and atoms are not free to migrate from one part of the metal to another, but have a limited freedom of movement about a mean position. The electrons are not constrained to any particular part of the metal, but are free to move

from one part to another, such movement being accompanied by collisions and changes in the direction of movement, in a manner similar to that accompanying the movement of molecules in a gas, considered from the standpoint of the kinetic theory of gases. The positive ions have been supposed by some to change their positions, by others not. The number of free electrons per cubic centimeter of metal is very large, being of the order of a billion billions. The mean free path of an electron scarcely exceeds one-millionth of a centimeter in any case. The number per cubic centimeter and the length of free path is different with different metals. In an ordinary metal at a uniform absolute temperature of *T* degrees all the particles of the metal are in motion, collisions are constantly occurring and the directions of the motion are such as result from chance. According to the doctrine of equipartition of energy the mean kinetic energies of the molecules of the atoms, of the positive ions and of the electrons are equal to each other and dependent upon the absolute temperature. Inasmuch as the masses of the electrons are much smaller than those of the other particles, the velocities of the electrons must be much greater.

Solid dielectrics probably contain some free electrons, although the number per unit volume is small compared with that in metals. To free electrons is due the conductivity of solid insulators that remain after surface leakage has been prevented. Free atomic ions are probably absent, since conditions through their mediation would result in a transport of matter with accompanying differences in the chemical and physical character of the surface layers of the dielectric when kept between conductors having a maintained difference of potential.

At all temperatures above absolute zero all bodies radiate energy. If the nature of the body be not changed by this radiation, that is, if it continues to radiate in the same manner, as long as its temperature is maintained constant by the addition of heat, the process is termed pure temperature radiation. If, on the other hand, the body changes because of the radiation and does not continue indefinitely to yield the same radiation, although its temperature is kept constant, the process is termed luminescence. The cause of some of the radiation in the latter case does not lie in the temperature of the system, but in some other source of energy. According as the extra supplied energy accompanies either chemical transformations, exposure to light, or the passage of electric currents, the processes are respectively termed chemico, photo, and electro-luminescence. The total radiation from a body of this class is made up of two parts—that due to its temperature and that due to the extra energy. If the intensity of radiation of a body within any region of wave-lengths is greater than that of a black body at the same temperature, luminescence must be present. This is frequently taken as a criterion for the detection of luminescence. The frequencies of luminescent radiations are more or less restricted, being often evidenced by bright-line spectral distributions. The electrons which yield these radiations are supposed to vibrate harmonically under conditions that are not yet understood. That their movements are not governed simply by chance seems to follow from the character of the spectra. Although change in the character of the material as a consequence of its yielding luminescent radiation may not be capable of detection by chemical analysis, yet the atomic and molecular systems are nevertheless doubtless undergoing constant changes, due to the loss or gain of electrons. The entrance of an electron into a system, or its ejection, must, without doubt, occasion complex harmonic disturbances of many or all the electrons in the system.

If luminescent radiation be confined chiefly to wave-lengths of the visible spectrum the luminous efficiency of the body becomes high. Herein rests the economic significance of the efforts being made to advance the art of lighting by means of vacuum tube and flaming arc lamps.

A very interesting example of luminescent radiation is that which is yielded by photogenic bacteria, which are frequently found in sea-water and upon meats and fish that have been directly or indirectly infected by

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* From Presidential Address at the Niagara Falls Convention of the American Institute of Electrical Engineers.