

MORTARS.

The guns denominated mortars were in special honor in the time of Vauban. It was, in fact, to "ricochet" firing that that great capturer of strongholds owed his memorable successes. Placing them in judiciously selected places, he pierced the faces of the works of the besieged and soon put their artillery material out of service. Such a result obtained, it only remained to make a breach and begin an assault, an operation which was an affair of but short duration. Mortars continued to be employed with no less success during the siege of Sebastopol. The Russians made use of them in large numbers, and rained upon

weapon presented by the Skoda establishment of Pilsen, Austria, and called a 9.36-inch siege and fortress gun (Fig. 2). This piece, which may be considered as typical of modern mortars, weighs 4700 pounds. It is mounted upon a cradle and consequently has a total weight of 7578 pounds. The platform, with the body of the mount, weighs 7779 pounds. The hydraulic recoil cylinder permits of a recoil of 12 inches. The shell weighs 297 pounds. The charge is 5 pounds of smokeless powder, which gives the projectile an initial velocity of 984 feet.

This material is transported by two carriages, the fore-carriages of which weigh 1210 pounds. The first carries the mortar and its cradle, and the second the

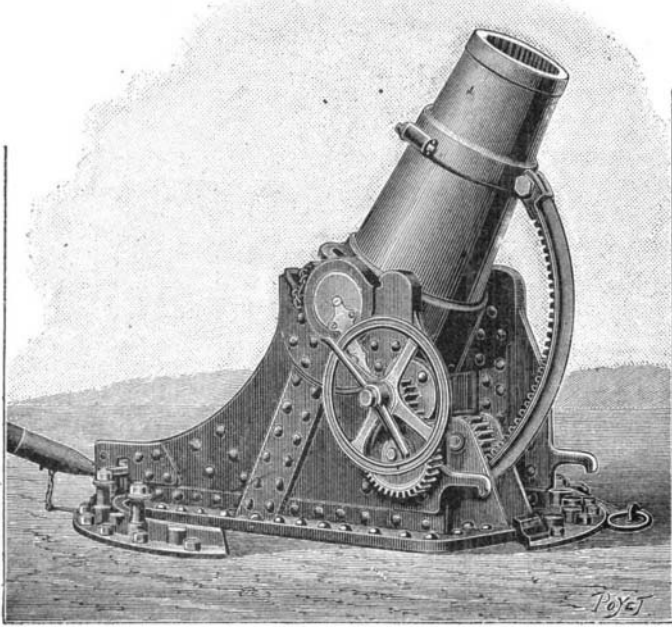


FIG. 1.—SAINT CHAMOND 8.5-INCH LIGHT RIFLE MORTAR.

the trenches of the besiegers an uninterrupted shower of bombs, which, fired at wide angles, left nothing under protection from their fragments. In the army of the allies there was organized a service of night observers, who, upon observing the train left in the sky by the fuse, made an estimate as to whether the bomb was to fall in their direction, and, when such was to be the case, gave the well-known cry: "Look out for the bomb!" Thereupon everyone squatted close to the parapet of the trench or lay flat upon the ground in order to escape the effects of the explosion. These big spherical projectiles have had their day; but, as for the mortars that fired them with so great noise, they still exist in name, yet how greatly transformed! Their chamber has been elongated and rifled; they are loaded at the breech just like other guns; and they are even arranged upon carriages with recoil cylinders. It is a far cry from these new weapons to the old smooth-bore mortars drawn upon rudimentary carriages.

Properly speaking, it may be said that there are now no longer any mortars. The pieces that we continue to style thus are merely short howitzers—howitzers themselves being simply short cannon. All ordnance is now of practically the same construction, the only differences between the various pieces residing in the caliber and length, the former of which permits of varying the weight of the projectile and the latter of increasing or diminishing its velocity.

Smooth-bore mortars disappeared and gave place

platform and the mount. The weight to be hauled is the same for both carriages, say, about 10,230 pounds.

As we have already intimated the names of guns have no longer any great significance. We have a proof of this in the designation given in different armies to short guns designed for campaign service. In Germany these are called "howitzers;" in France, "short guns," and in Russia, "mortars." In fact, the last Exposition showed us a Russian campaign mortar of the Engelhart system—a very ingeniously constructed piece in which the recoil was limited by the action of rubber buffers.

Upon the whole we may report that there are no longer any mortars. The name may still exist in Austria and Russia, but, in reality, none of the pieces that continue to be designated thus has the least affinity to the weapons that permitted Vauban to attain such wonderful results. There is no reason for being surprised at such disappearance when we take into account the wonderful progress that has been made in modern armament. As compared with the present guns the old mortars, even those with which the maritime coasts were studied, are nothing but weapons of too ordinary power. Bombs were certainly respectable projectiles by reason of their weight; but the slowness with which they were fired, the feeble velocity with which they were impelled, and their slight precision gave them nothing more than a ridiculous efficiency. It was but natural that they, along with mortars, should disappear.—For the

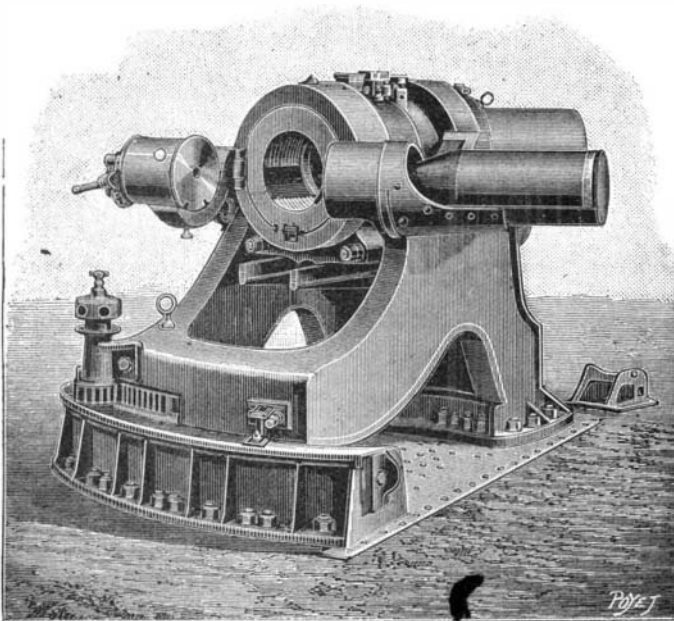


FIG. 2.—SKODA 9.36-INCH SIEGE AND FORTRESS MORTAR.

to rifled ones after the war of 1870. Breech-loading was not immediately adopted for the latter, which were at first loaded at the muzzle. The closing of the chamber by the projectile was assured by what was called an expansion ring, which expanded under the effect of the pressure of the powder gas.

The Saint Chamond Works was one of the first to construct breech-loading rifled mortars. The one which we represent (Fig. 1) was experimented with at Bourges by the War Department fifteen years ago.

This piece, which had a bore of 8.66 inches, was without recoil and fired shells 43.3 inches in length containing 66 pounds of explosive powder.

At the Exposition of 1900 there was exhibited a

above particulars and the engravings we are indebted to La Nature.

Silver Polishing Soap.—Stir 10 kilos of caustic soda lye of 28 deg. Bé. into 10 kilos of coconut oil at 30 deg. C. and heat the whole at a temperature of not exceeding 50 deg. C. until the saponification is completed. Now mix 30 kilos of powdered tripoli intimately with the above and pour the soap into iron molds or wooden boxes lined with zinc. This soap may be colored with fat-soluble aniline dye previously stirred with a little coconut oil.—Il Profumiere e Saponiere Italiano.

THE PROGRESS OF ELECTRIC SPACE TELEGRAPHY.*

By G. MARCONI.

WIRELESS telegraphy, or telegraphy through space without connecting wires, is a subject which at present is probably attracting more world-wide attention than any other practical development of modern electrical engineering. That it should be possible to actuate an instrument from a distance of hundreds or thousands of miles and oblige it at will to reproduce audible or visible signals through the effects of electrical oscillations transmitted to it without the aid of any continuous artificial conductor, strikes the minds of most people as being an achievement both wonderful and mysterious. If we examine the subject closely we may, however, come to the conclusion that, although telegraphy through space is certainly wonderful, as are likewise all natural and physical phenomena, yet it is certainly in no way more wonderful than the transmission of telegrams along an ordinary telegraph wire. The light and heat waves of the sun and stars travel to us through millions of miles of space, and sound also reaches our ears without requiring any artificial conductor. It is not, therefore, wonderful that man should have devised means by which he is enabled to confine electricity conveying messages or power to a wire and cause the effect which we call an electric current to follow all the turns and convolutions which may exist in the wire?

We find that the first systems of telegraphy used by mankind were truly wireless. A bonfire built on a hill by a band of aboriginal Indians conveyed a signal wirelessly by etheric waves—in this case light waves—to Indians on another hill, perhaps miles distant. Even to-day there are innumerable systems of what may truly be called wireless telegraphy in practical use. A red light at a railway crossing conveys a signal by waves through the ether to the eye of the engine driver. The red light is the transmitter, the eye the receiver.

The method of space telegraphy of which I intend speaking to-night is founded on a comparatively new way of controlling and detecting certain kinds of etheric waves, much slower in rate of vibration than light waves, called Hertzian waves, after the scientist who first demonstrated their existence. The mathematical and experimental proof by Clerk Maxwell and Heinrich Hertz of the identity of light and electricity, and the knowledge of how to produce and detect certain previously unknown ether waves, made possible this new method of communication. I think I am right in saying that the importance of the discoveries of Maxwell and Hertz was realized by very few, and even, perhaps, so recently as a year ago a great number of scientific men would have hardly foreseen the advances which have been made in so brief a time in the art of space telegraphy.

The time allowed for this discourse does not permit me to describe all the various steps which have made possible the results recently obtained nor to describe the work of the numerous workers who have contributed to the advance of the subject, but I hope it may be of interest if I describe the various problems which have lately been solved, and the very interesting developments which have taken place in my own work during the last few months. I shall first briefly describe my system as used in my early experiments six years ago, and afterward endeavor to explain the various improvements and modifications which have since been introduced into it.

The transmitter consists of a modified form of Hertzian oscillator, the main feature of which is in having one sphere of the spark discharger earthed and the other connected to an elevated capacity area or to a comparatively vertical wire. The two spheres are also connected to the ends of the secondary winding of an induction coil or transformer. When the key is pressed the current of the battery is allowed to actuate the spark coil, which charges the spheres and the vertical wire, which, when discharging, causes a rapid succession of sparks to pass across the spark-gap. The sudden release caused by the spark discharge of the electrical strain or displacement created along certain lines of electric force through space by the charged wire causes some of the electrical energy to be thrown off in the form of a displacement wave in the ether, and, as a consequence, the vertical wire becomes a radiator of electric waves. In this connection it is interesting to remember that Lord Kelvin showed mathematically more than 40 years ago the precise conditions under which such a discharge as we are considering would be oscillatory. It is easy to understand how, by pressing the key for longer or shorter intervals, it is possible to emit a long or short succession of impulses or waves which, when they influence a suitable receiver, reproduce on it a long or short effect, according to their duration, in this way reproducing the Morse or other signals transmitted from the sending station.

The receiver consists of a coherer (on the nature of which I hope to make a few further remarks later) placed in a circuit containing a local cell and a sensitive telegraph relay actuating another circuit, which works a trembler or decoherer and a recording instrument. In its normal condition the resistance of the coherer is infinite, or at least very great, and the current of the battery cannot pass through it to actuate the instruments, but when influenced by electric waves the coherer becomes a comparatively good conductor, its resistance falling to between 100 and 500 ohms. This allows the current from the local cell to actuate the relay, which in turn causes another stronger current to work the recording instrument and also the tapper or decoherer, which is so arranged as to tap or shake the coherer, and in this way restore its sensitiveness. The practical result is that the circuit of the recording instrument is closed for a time equal to that during which the key is pressed at the transmitting station, and in this way it is possible to obtain a graphic, acoustic or optical reproduction of the movements of the key at the sending station. One end of the tube, or coherer, is connected to earth and the other to an insulated conductor, preferably

*Lecture delivered at the Royal Institution, June 13.

terminating in a capacity area similar in every respect to the one employed at the transmitting station.

I noticed that by employing similar vertical rods at both stations, it was possible to detect the effects of electric waves, and in that way convey the intelligible alphabetical signals over distances far greater than had previously been believed possible, and by means of similar arrangements distances of transmission up to about 100 miles were obtained.

It was soon, however, realized that so long as it was possible to work only two installations within what I may call their sphere of influence, a very important limit to the practical utilization of the system was imposed. Without some practical method of tuning the stations it would have been impossible to work a number in the vicinity of each other at the same time without interference caused by the mixing of messages. The new methods of connection which I had adopted in 1898, i. e., connecting the receiving vertical wire or aerial directly to earth instead of to the coherer, and by the introduction of a proper form of oscillation transformer in conjunction with a condenser so as to form a resonator tuned to respond best to waves given out by a given length of aerial wire—were important steps in the right direction. I referred at length to this improvement in the discourse which I had the honor to deliver at this table on February 2, 1900. I had, however, realized at the time that one great difficulty in the way of achieving the desired effects was caused by the action of the transmitting wire. A straight rod in which electrical oscillations are set up forms, as is well known, a very good radiator of electrical waves. In all what we call good radiators electrical oscillations set up by the ordinary spark-discharge method cease or are damped out very rapidly, not necessarily by resistance, but by electrical radiation removing the energy in the form of electric waves.

It is a well-known fact that when one of two tuning forks having the same period of vibration is set in motion, waves will form in the air, and the other tuning fork, if in suitable proximity, will immediately begin to vibrate in unison with the first. In the same way a violin player, sounding a note on his instrument, will find a response from a certain wire in a piano nearby, that particular wire, out of all the wires of the piano, happening to be the only one which has a period of vibration identical with that of the musical note sounded by the violinist. Tuning forks and violins, of course, have to do with air waves and wireless telegraphy with ether waves, but the action in both cases is similar. It is very important to take into consideration the one essential condition which must be obtained in order that a well-marked tuning or electrical resonance may take place. Electrical resonance, like mechanical resonance, essentially depends upon the accumulated effect of a large number of small impulses properly timed. Tuning can only be obtained if a sufficient number of these timed electrical impulses reach the receiver. As Prof. Fleming so graphically puts it in one of his lectures on electrical oscillations, to "set a pendulum in vibration by puffs of air we must not only time the puffs properly, but keep on puffing for a considerable period." It is, therefore, clear that a dead-beat radiator, i. e., one that does not give a train or succession of electrical oscillations—is not suitable for tuned or syntonized space telegraphy.

As I pointed out before a transmitter consisting of a vertical wire discharging through a spark-gap is not a persistent oscillator. Its electrical capacity is comparatively so small and its capability of radiating waves so great that the oscillations which take place in it must be considerably damped. In this case receivers or resonators of a considerably different period or pitch will respond and be affected by it.

Early in 1900 I obtained very good results with another arrangement in which the radiating and resonating conductors each take the form of two concentric cylinders, the internal cylinder being earthed. By using zinc cylinders only 7 meters high and 1.5 meters in diameter good signals could easily be obtained between St. Catherine's Point, Isle of Wight, and Poole, over a distance of 30 miles, these signals not being interfered with or read by other wireless telegraph installations worked by my assistants or by the Admiralty in the immediate vicinity. The capacity of the transmitter due to the internal conductor is so large that the energy set in motion by the spark discharge cannot all radiate in one or two oscillations, but forms a train of slowly-damped oscillations, which is just what is required. A simple vertical wire may be compared with an empty teapot, which, after being heated, would cool very rapidly, and the concentric cylinder system with the same teapot filled with hot water, which would take a very much longer time to cool. In the receiver the closely adjacent cylinders which give it large electrical capacity cause it to be a resonator possessing a very decided period of its own, and it becomes no longer apt to respond to frequencies which differ from its own particular period of electrical oscillation, nor to be interfered with by stray ether waves which are sometimes caused by atmospheric disturbances, and which occasionally prove troublesome during the summer.

Another successful system of tuning or syntonizing the apparatus was the outcome of a series of experiments carried out with the discharge of condenser or Leyden jar circuits. I tried by means of associating with the radiating wire, or capacity, a condenser circuit, which is known to be a persistent oscillator, to set up the required number of oscillations in the radiator. An arrangement consisting of a circuit containing a condenser and a spark-gap constitutes a very persistent oscillator. Prof. Lodge has shown us how, by placing it near another similar circuit it is possible to demonstrate interesting effects of resonance by the experiment usually referred to as that of Lodge's syntonized jars. But, as Lodge points out, "a closed circuit such as this is a feeble radiator and a feeble absorber, so that it is not adapted for action at a distance." I very much doubt if it would be possible to effect an ordinary receiver even at a few hundred yards. It is, however, interesting to notice how easy it is to cause the energy contained in the circuit of this arrangement to radiate into space. It is sufficient to place near one of its sides a straight

metal rod or good electrical radiator, the only other condition necessary for long-distance transmission being that the period of oscillation of the wire or rod should be equal to that of the nearly closed circuit. Stronger effects of radiation are obtained if the radiating conductor is partly bent round the circuit containing the condenser (so as to resemble the circuits of a transformer).

My first trials with this system were not success-

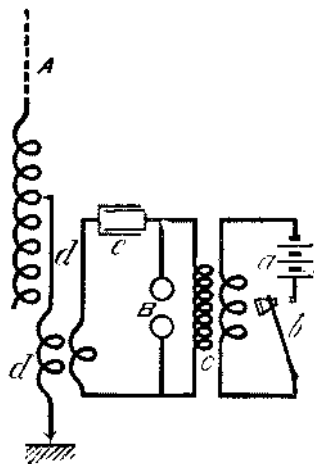


FIG. 1.

ful, in consequence of the fact that I had not recognized the necessity of attempting to tune to the same period of electrical oscillations (or octaves) the two electrical circuits of the transmitting arrangement (these circuits being the circuit consisting of the condenser and primary of the transformer and the aerial or radiating conductor and secondary of the transformer). Unless this condition is fulfilled, the different periods of the two conductors create oscillations of a different frequency and phase in each circuit, with the result that the effects obtained are feeble and unsatisfactory on a tuned receiver. The syntonized transmitter is shown in Fig. 1. The period of oscillation of the vertical conductor, A, can

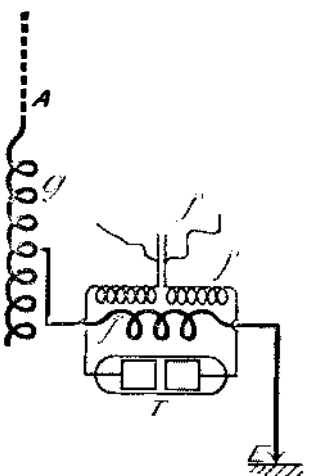


FIG. 2.

be increased by introducing turns of wire, or decreased by diminishing their number, or by introducing a condenser in series with it. The condenser in the primary circuit is constructed in such a manner as to render it possible to vary its electrical capacity.

The receiving station arrangements are shown in Fig. 2. Here we have a vertical conductor connected to earth through the primary of a transformer, the secondary circuit of which is joined to the coherer or detector. In order to make the tuning more marked, I place an adjustable condenser across the coherer in Fig. 3. Now, in order to obtain best results, it is necessary that the free period of electrical oscillation of the vertical wire primary of transformer and earth

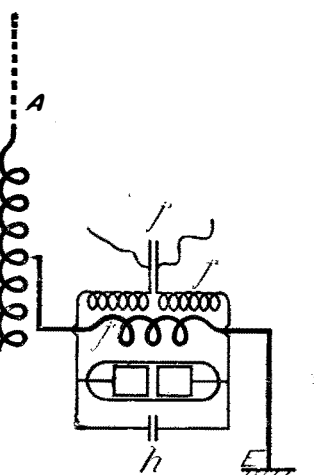


FIG. 3.

connection should be in electrical resonance with the second circuit of the transformer, which includes the condenser. I stated that in order to make the tuning more marked a condenser is placed across the coherer. This condenser increases the capacity of the secondary resonating circuit of the transformer, and in the case of a large series of comparatively feeble but properly timed electrical oscillations being received, the effect of the same is summed up until the E. M. F. at the terminals of the coherer is sufficient to break down its insulation and cause a signal to be recorded. In order that the two systems, transmitter and receiver, should be in tune it is necessary (if we assume the resistance

to be very small or negligible) that the product of the capacity and inductance in all four circuits should be equal.

It is easy to understand that if we have several stations, each tuned to a different period of electrical vibration, and of which the corresponding inductance and capacity at the transmitting station are known, it will not be difficult to transmit to any one of them, without danger of the message being picked up by the other stations for which it is not intended. But better than this we can connect to the same vertical sending wire, through connections of different inductance, several differently tuned transmitters, and to the receiving vertical wires a number of corresponding receivers. Different messages can be sent by each transmitter connected to the same radiating wire simultaneously and received equally simultaneously by the vertical wire connected to differently tuned receivers. This result, which I believe was quite novel at the time, I showed to several friends of mine, including Dr. J. A. Fleming, F.R.S., nearly two years ago. Dr. Fleming made mention of the results he had seen in a letter to the London Times dated October 4, 1900. I have further noticed that the tuning can be further improved by the combination of the two systems described. In this case the cylinders are connected to the secondary of the transmitting transformer, and the receiver to a properly-tuned induction coil, and all circuits must be tuned to the same period as already described. This arrangement is going to be further tested in long-distance experiments shortly to be undertaken between England and Canada.

The syntonized systems have not been applied generally to ships, as it has always been considered an advantage that each ship should be able, especially in case of distress, to call up any other ship or ships which may happen to be at the time within the range of its transmitter, but in the case of land stations the syntonized method has been applied in several instances where necessity demanded it. Thus at the testing stations which maintain communication between St. Catherine's, Isle of Wight, and Poole, in Dorset, when electric waves of a certain frequency are used, no interference whatever can be caused by the working of the Admiralty installations in the vicinity. The long-distance station at Poldhu, Cornwall, is able to transmit signals decipherable on a tuned receiver on a ship at over 1000 miles distance, while the Lloyd's wireless station at the Lizard, only 7 miles away, is not affected by the powerful waves radiated from Poldhu if tuned to a different frequency.

I am not at all prepared to say that under no possible circumstances could a wireless message transmitted between syntonized instruments be tapped or interfered with, but I wish to point out that it is now possible to work a considerable number of wireless telegraph stations simultaneously in the vicinity of each other without the messages suffering from any interference. Of course, if a powerful transmitter, giving off waves of different frequencies, is actuated near one of the receiving stations it may prevent the reception of messages, but the ordinary systems of communication through wires may be likewise affected. Prof. O. J. Lodge, in a report of his experiments in magnetic space telegraphy, mentions that he was able to interfere with the working of the ordinary wire telephone system in the city of Liverpool. Sir W. H. Preece has also published results which go to show that it is possible to pick up at a distance on another circuit the conversation which may be passing through a telephone wire. About two years ago, at Cape Town, it was found impossible to work the cables landing there during certain hours when the electric tramways of the town were running, and the matter became subsequently the subject of litigation between the companies concerned. Prof. Fleming, who has witnessed the working of a great number of syntonized wireless telegraph stations, was sufficiently impressed by what he saw to make the following statement in his Cantor lectures on "Electrical Oscillations and Electric Waves," delivered before the Society of Arts in December, 1900: "The objections as to interference of stations which imperfectly-informed persons are in the habit of raising with regard to Mr. Marconi's system of wireless telegraphy, as a matter of fact no longer exist."

I shall now say a few words on the subject of the detector of the electric waves, called sometimes "the electric eye," which consists of that essential part of the receiving apparatus especially affected by the electrical oscillations. In all wireless telegraph apparatus used up to quite a recent date, a detector, now called a coherer, has been employed. This detector is based on discoveries and observations made by S. A. Varley, Prof. Hughes, Colzocchi, Onesti, and especially Prof. Branly. Prof. O. J. Lodge has made large use of this apparatus, which he first named "coherer," in the very numerous experiments and studies he has carried out on the effects produced by Hertzian waves. The form of coherer I have found most trustworthy and reliable for long-distance work consists of a small glass tube about 4 centimeters long, into which two metal pole-pieces are tightly fitted. They are separated from each other by a small gap, which is partly filled with a mixture of nickel and silver filings. Provided such a coherer is properly constructed, and the tapper and relay in good adjustment, it proves to be quite reliable when within the range of the transmitting station. Experiments with syntonized systems have, however, shown that certain kinds of coherers can be far more advantageously employed than others. One apparently all-important condition is that the resistance of the coherer in its sensitive state, or after being tapped, should appear to be infinite when measured with an E.M.F. of about 1 volt. If the tapping does not entirely do away with the conductivity of the filings very poor results are obtained, which can be explained as follows. According to the systems I have described, electrical sympathy between the transmitter and receiver is dependent on the proper electrical resonance of the various circuits of the transformers used in the receivers. The condenser and secondary of the transformer must not be partially short-circuited by the coherer, otherwise the oscillations cannot mount up or sum up their effect, as is essential in order to produce the difference of potential at the ends of the coherer necessary for breaking down its resistance; but the electrical oscillations will leak across the con-

ductive coherer without causing it to record any signal. Of course, the condenser is short-circuited when the filings cohere under the influence of the received oscillations; but in this case the signal is already recorded, and the tapper at once restores the coherer to its non-conducting condition, and in this way restores its sensitiveness.

By using coherers containing very fine filings the necessary condition of non-conductivity when in a sensitive state is obtained. Coherers have lately been tried which will work to a certain extent satisfactorily without the necessity of employing any tapper or decoherer in connection with them. Nearly all are dependent on the use of carbon microphonic contact or contacts which possess the curious quality of partially re-acquiring spontaneously their high resistance condition after the effect of the electrical oscillations has ceased. This enables one to obtain a far greater speed of reception than is possible by means of a mechanically-tapped coherer, the inertia of the relay and tapper which are used in connection with it being necessarily sluggish in their action. In all these self-decohering coherers a telephone which is affected by the variations of the electric current caused by the changes in conductivity of the coherer is used in place of the recording instrument. It has not yet been found possible, so far as I am aware, to actuate a recording instrument or a relay by means of a self-restoring coherer. The late Prof. Hughes was the first, I believe, to experiment with and receive signals on one of these coherers associated with a telephone. His experiments were carried out as early as 1879, and I regret that this pioneer work of his is not more generally known. Other self-restoring coherers were proposed by Profs. Tommasina, Popoff, and others, but one which has given good results when syntonic effects were not aimed at was (according to official information communicated to me) designed by the technical personnel of the Italian navy. This coherer, at the request of the Italian government, I tested during numerous experiments. It consists of a glass tube containing plugs of iron with between them a globule of mercury. Lieut. Solari, who brought me this coherer, asked me to call it the "Italian Navy Coherer." Recently, however, a technical paper gave out that a signalman in the Italian navy was the inventor of the improved coherer, and I was at once accused in certain quarters of suppressing the alleged inventor's name. I therefore wrote to the Italian Minister of Marine, Admiral Morin, asking him to make an authoritative statement, to which I could refer in the course of this address, of the views of the Italian Admiralty on the matter. The head of the Italian navy was good enough to reply to me by letter, dated the 4th inst., in which he makes the following statement, which I have translated from the original Italian: "The coherer has been with good reason baptized with the name of 'Italian Navy Coherer,' as it must be considered fruit of the work of various individuals in the Royal navy and not that of one." These non-tapped coherers have not been found to be sufficiently reliable for regular or commercial work. They have a way of cohering permanently when subjected to the action of strong electrical waves or atmospheric-electrical disturbances, and have also an unpleasant tendency toward suspending action in the middle of a message. The fact that their electrical resistance is low and always varying, when in a sensitive state, causes them to be unsatisfactory for the reasons I have already enumerated when worked in connection with my system of syntonic wireless telegraphy.

These coherers are, however, useful if employed for temporary tests in which the complete accuracy of messages is not all-important, and when the attainment of syntonic effects is not aimed at. They are especially useful when using receiving vertical wires supported by kites or balloons, the variations of the height of the wires (and, therefore, of their capacity) caused by the wind making it extremely difficult to obtain good results on a syntonic receiver.

Coherers have long been considered as constituting almost the essential basis of electric space telegraphy, and although many other detectors of electric waves existed, none of them possessed a sensitiveness which even approached that of a coherer, and most of them were also unsuitable for the reception of telegraphic messages. With a view to producing a receiver which could be worked at a much higher speed than a coherer, I was fortunate enough to succeed in constructing a magnetic detector of electric waves, based on a principle essentially different from that of the coherer, and which I think leaves all coherers far behind in speed, facility of adjustment and efficiency when worked in tuned circuits. This detector, which I had the honor of describing in detail before the Royal Society yesterday, possesses I believe a sensitiveness which surpasses that of the best coherers. The magnetization and demagnetization of steel needles by the effect of electrical oscillations has long been known and was noted especially by Prof. T. Henry, Aloria, Lord Rayleigh and others. Mr. E. Rutherford also has described a magnetic detector of electric waves based on the partial demagnetization of a small core composed of fine steel needles previously magnetized to saturation. By means of a magnetometer Mr. Rutherford succeeded in 1895 in tracing the effects of his electrical radiator up to a distance of three-quarters of a mile across Cambridge. But Mr. Rutherford's arrangement is not suitable for the reception of telegraphic messages in consequence of the fact that a careful process of remagnetization, which requires some time to effect, is necessary in order to restore its sensitiveness after the receipt of each impulse. Mr. Rutherford's arrangement is also considerably less sensitive than a coherer.

The detector which I am about to describe is, in my opinion, based upon the decrease of magnetic hysteresis, which takes place in iron when under certain conditions it is exposed to the effect of high frequency oscillations or Hertzian waves. As employed by me, it has been constructed in the following manner: On a core of thin iron or steel, but preferably hard drawn iron, are wound one or two layers of thin insulated copper wire. Over this winding insulating material is placed, and over this, again, another longer winding of thin copper wire contained in a narrow bobbin. The

ends of the winding nearest the iron core are connected, one to earth and the other to an elevated conductor, or they may be connected to the secondary of a suitable receiving transformer or intensifying coil, such as are employed for syntonic wireless telegraphy. The ends of the other winding are connected to the terminals of a telephone or other suitable receiving instrument. Near the ends of the core, or in close proximity to it, is placed a horseshoe magnet, which, by a clock-work arrangement, is so moved or revolved as to cause a slow and constant change or successive reversals in the magnetization of the piece of iron. I have noticed that if electrical oscillations of suitable period be sent from a transmitter, rapid changes are effected in the magnetization of the iron wires, and these changes necessarily cause induced currents in the windings, which in their turn reproduce on the telephone with great clearness and distinctness the telegraphic signals which may be sent from the transmitting station. Should the magnet be removed or its movement stopped, the receiver ceases to be perceptibly affected by the electric waves even when these are generated at very short distances from the radiator.

I have had occasion to notice that the signals audible in the telephone are weakest when the poles of the rotating magnet have just passed the core, and are increasing their distance from it, while they are strongest when the magnet's poles are approaching the core. Good results have also been obtained by keeping the magnet fixed, and using an endless iron rope or core of thin wires revolving on pulleys (worked by clock-work), which cause the iron to travel through the copper wire windings, in proximity to, preferably, two horseshoe magnets with their poles close to the windings, care being taken that their poles of the same sign are adjacent. This detector has been successfully employed for some time in the reception of wireless telegraphic messages between St. Catherine's Point, Isle of Wight, and the North Haven, Poole, over a distance of 30 miles, also between Polhu, in Cornwall, and Poole, in Dorset, over a distance of 152 miles, of which 109 are over sea and 43 over high land.

It would, no doubt, be possible to obtain signals by causing the iron core to act directly on a telephone diaphragm, and in this case the secondary winding could be omitted. This detector, as I have already stated, appears to be more sensitive and reliable than a coherer, nor does it require any of the adjustments or precautions which are necessary for the good working of the latter. It possesses a uniform and constant resistance, and, as it will work with a much lower E.M.F., the secondaries of the tuning transformers can be made to possess much less inductance, their period of oscillation being regulated by a condenser in circuit with them, which condenser may be much larger (in consequence of the smaller inductance of the circuit) than those used for the same period of oscillation in a coherer circuit, with the result that the receiving circuits can be tuned much more accurately to a particular radiator of fairly persistent electric waves. As a call, a coherer in circuit, with a relay working a bell, can always be used, and if it is found possible to make the magnetic detector record on a registering instrument (as to the possibility of which the results of recent tests have left little doubt in my mind), it may be found possible to receive wireless telegraph messages at a speed of several hundred words a minute. At present, by means of this detector, it is possible to read about 30 words per minute.

The considerations which led me to the construction of the above-described detector are the following: It is a well-known fact that, after any change has taken place in the magnetic force acting on a piece of iron, some time elapses before the corresponding change in the magnetic state of the iron is complete. If the applied magnetic force be caused to effect a cyclic variation, the corresponding induced magnetic variation in the iron will lag behind the changes in the applied force. To this tendency to lag behind Prof. Ewing has given the name of magnetic hysteresis. It has been shown also by Profs. Gerosa, Finzi and others, that the effect of alternating currents or high-frequency electrical oscillations acting upon iron is to reduce considerably the effects of magnetic hysteresis, causing the metal to respond readily to any influence which may tend to alter its magnetic condition. The effect of electrical oscillations probably is to bring about a momentary release of the molecules of iron from the constraint in which they are ordinarily held, diminishing their retentiveness and consequently decreasing the lag in the magnetic variation taking place in the iron. I therefore anticipated that the group of electrical waves emitted by each spark of a Hertzian radiator would, if caused to act upon a piece of iron which is being subjected at the same time to a slowly varying magnetic force, produce sudden variations in its magnetic hysteresis, which would cause others of a sudden or jerky nature in its magnetic condition. In other words, the magnetization of the iron, instead of slowly following the variations of the magnetic force applied, gives a sort of jump each time it is affected by the electric waves emitted by each spark of the radiator. These jerks in the magnetic condition of the iron would, I thought, cause induced currents in a coil of wire of strength sufficient to allow the signals transmitted to be detected intelligibly on a telephone, or perhaps even read on a mirror galvanometer. The results obtained go to confirm my belief that this detector can be advantageously substituted for the coherer for the purposes of long-distance space telegraphy.

During the last few years the developments in the practical appliances of my system have been exceedingly rapid. Time does not allow me to give you an account of the many cases in which it has proved its usefulness, but it may be sufficient if I mention that Lloyd's have adopted the system exclusively for use at their stations at home and abroad for a period of 14 years, and that no less than 17 liners plying across the Atlantic carry permanent installations. In more than one case recorded in the daily papers the system has been of service to vessels in distress, especially in the English Channel. No less than 40 land stations (most of which are controlled by the corporation of Lloyd's) are being equipped with the system in Great Britain and Europe, and over 40 vessels in H. M. navy

carry installations. The adoption of my system in the Royal navy has brought about a certain slight change in the rig of the ships. Some naval officers believe that this change improves the ship's appearance; others think the contrary.

The Italian Admiralty, after experimenting for some time with the self-decohering coherers to which I have referred before, has informed me officially, by a letter dated May 24 last, of its decision to equip their war vessels with the same apparatus as has been successfully employed on the transatlantic liners. On these liners commercial use is made of the system for the convenience of passengers, and as an illustration of its commercial workableness I might mention that lately the "Campania" and "Lucania" of the Cunard line have been collecting as much as £60 each trip in receipts derived from passengers' wireless messages.

Nearly two years ago the facility with which communication was possible over distances of nearly 200 miles, and the improvements in syntonic methods introduced, together with the ascertained fact of the non-interference of the curvature of the earth, led me to decide to recommend the construction of a large power station in Cornwall and another one at Cape Cod, Mass., U. S. A., in order to test whether, by the employment of much greater power, it might not be possible to transmit messages across the Atlantic, and establish a trans-oceanic commercial communication which the monopoly of the Postmaster-General will not apparently permit between two stations if both are situated in Great Britain. An unfortunate accident to the masts at Cape Cod seemed likely to postpone the experiments for several months, when I came to the conclusion that while the necessary repairs there were being carried out I would use a purely temporary installation in Newfoundland for the purpose of a transatlantic experiment, from which I might, at any rate, be able to judge how far the arrangements in Cornwall had been conducted on right lines. Before describing the results it may be useful if I give a brief description of the nature of the apparatus used at the transmitting and receiving stations.

The transmitter at Polhu was similar in principle to the syntonic one I have already described, but the elevated conductor at the transmitting station was much larger, and the potential to which it was charged very much in excess of any that had previously been employed, the amount of energy to be used in this transmitting station having been approximately determined by me prior to its erection. The transmitting elevated conductor consisted of 50 almost vertical naked copper wires, suspended at the top by a horizontal wire stretched between two poles, each 48 meters high, and placed 60 meters apart. These wires were separated from each other by a space of about a meter at the top, and, after converging together, were connected to the transmitting instruments at the bottom. The potential to which these conductors were charged during transmission was sufficient to cause sparking between the top of the said wires and an earthed conductor across a space of 30 centimeters of air. The general engineering arrangements of the electric power station erected at Polhu for the execution of these plans and for creating the electric waves of the frequency which I desired to use were made by Dr. J. A. Fleming, F.R.S., who also devised many of the details of the appliances for producing and controlling the electric oscillations. These, together with devices introduced by me, and my special system of syntonization of inductive circuits, have provided an electric wave-generating plant more powerful than any hitherto constructed. Mr. R. N. Vyvyan and Mr. W. S. Entwistle have also greatly assisted me in the experiments carried out with the very high tension electrical apparatus employed.

The first experiments were carried out in Newfoundland last December, and every assistance and encouragement was given me by the Newfoundland government. As it was impossible at that time of the year to set up a permanent installation with poles, I carried out experiments with receivers joined to a vertical wire about 400 feet long, elevated by a kite. This gave a very great deal of trouble, as in consequence of the variations of the wind, constant variations in the electrical capacity of the wire were caused. My assistants in Cornwall had received instructions to send a succession of "S's," followed by a short message at a certain pre-arranged speed, every 10 minutes, alternating with five minutes rest during certain hours every day. Owing to the constant variations in the capacity of the aerial wire it was soon found out that an ordinary syntonic receiver was not suitable, although a number of doubtful signals were at one time recorded. I, therefore, tried various microphonic self-restoring coherers placed in the secondary circuit of a transformer, the signals being read on a telephone. With several of these coherers, signals were distinctly and accurately received, and only at the pre-arranged times, in many cases a succession of "S's" being heard distinctly although, probably in consequence of the weakness of the signals and the unreliability of the detector, no actual message could be deciphered. The coherers which gave the signals were one containing loose carbon filings, another, designed by myself, containing a mixture of carbon dust and cobalt filings, and thirdly, the "Italian Navy Coherer," containing a globule of mercury between two plugs. For the good results obtained I was very much indebted to two of my assistants, Mr. G. S. Kemp and Mr. P. W. Paget, who gave me very efficient aid during the tests, which the extremely severe weather prevailing in December in Newfoundland made exceedingly difficult to carry out.

The result of these tests was sufficient to convince myself and my assistants that, with permanent stations at both sides of the Atlantic, and by the employment of a little more power, messages could be sent across the ocean with the same facility as across much shorter distances. The experiments could not be continued or extended in consequence of the action which the cable company, which claims all telegraphic rights in Newfoundland, saw fit to take at the time. Having received a most generous invitation from the government of the Dominion of Canada to continue my operations in the Dominion, it was thought undesirable to continue the experiments in Newfoundland, where I

should have probably been landed into litigation with the telegraph company. I am glad to say that the Canadian government, on the initiation of Sir Wilfred Laurier and Mr. Fielding, has shown itself most enterprising in the matter, and not only encouraged the erection of a large station in Nova Scotia, but actually granted a subsidy of £16,000 toward the erection of this transatlantic station, the object of which is to communicate with England from the coast of Nova Scotia. It is anticipated that the Canadian station will be ready for further tests very shortly. Another station for the same purpose is being erected on the United States coast.

Toward the end of February of this year I thought it desirable to test how far the messages transmitted by the powerful station at Polshu could be detected on board a ship. The ship selected was the "Philadelphia," of the American line. The receiving aerial conductor was fixed to the mast, the top of which was about 60 meters above sea level. As the elevated conductor was fixed, and not floating about with a kite, as in the case of the Newfoundland experiments, very good results were obtained on an ordinary syntonic receiver, similar to those I have already described, and the signals were all recorded on tape by the ordinary Morse recorder. Readable messages on tape were received up to a distance of 1551 miles from Cornwall, and indications were received as far as 2099 miles. Most of the messages were received in the presence of the captain or the chief officer of the ship, who were good enough to sign the tapes. I have some of these tapes here, in a frame, and they can be examined at the conclusion of my discourse. It is curious to observe that signals could not be received at over 900 miles by any of the self-restoring coherers. The reason for this lies probably in the fact that the tuned receiver when connected to a fixed aerial is more efficient. Another result of considerable scientific interest was that at distances of over 700 miles the signals transmitted during the day failed entirely, while those sent at night remained, as I have stated, quite strong up to 1551 miles, and were even decipherable up to a distance of 2099 miles. This result, which I had the honor of describing before the Royal Society yesterday afternoon, may be due to the dis-electricification of the very highly charged transmitting elevated conductor operated by the influence of daylight.

I regret time does not permit me to give you the views which have been expressed with reference to this phenomenon. I do not think, however, that the effect of daylight will be to confine the working of transatlantic wireless telegraphy to the hours of darkness, as sufficient sending energy can be used during daytime, at the transmitting station, to make up for the loss of range of the signals, and therefore this business of communicating across the Atlantic will not be one of those works of darkness with which some people connected with cable companies would seem disposed to class it. It is, however, probable that had I known of this effect of light at the time of the Newfoundland experiments, and had tried receiving at night-time, the results would have been much better than those that were obtained.

The day is rapidly approaching when ships will be able to be in touch and communication with the shore across all oceans, and the quiet and isolation from the outside world which it is still possible to enjoy on board ship will, I fear, soon be things of the past. However great may be the importance of wireless telegraphy to ships and shipping, I believe it will be of even greater importance to the world if found workable and applicable over such great distances as those which divide Great Britain from her colonies and from America. Any of those who have lived in the colonies will easily appreciate what a hardship it is to have to wait, perhaps, four or five weeks before receiving an answer to a letter sent home. The cable rates are at present prohibitive to a vast majority of people. May it not, perhaps, be for wireless telegraphy to supply the want?

I apologize for having kept you so long, but I cannot help reading you, in conclusion, a short extract from a leading article in the London Times of Saturday, December 21, 1901, published at the time of the Newfoundland experiments. And I do so because it expresses in language of admirable clearness the sentiments with which I myself regard this subject: "It would probably be difficult to exaggerate the good effect of wireless telegraphy if, as Mr. Marconi and Mr. Edison evidently believe, and as the Anglo-American Company evidently fear, it can at no distant time be developed into a commercial success. The expense of telegraphy to distant countries is at present prohibitive to vast numbers of people, and even those who use it do so only in respect of matters of great urgency, or in which large money interests are at stake. The reason of the high charges must be sought, of course, in the enormous costliness of the plant, both in its original construction and in its maintenance and repair. A system of aerial telegraphy which would not require an expensive plant, and through which, therefore, messages might be sent at moderate rates, would soon become a potent agent in cementing those ties between Great Britain and the colonies which other recent events have done so much to strengthen and even to create. A system of comparatively cheap telegraphs would do for the British Empire very much what was done by the penny post for the United Kingdom. The pathetic story of Rowland Hill, whose efforts to establish cheap postage originated in the sympathy he felt for a poor girl in a Cumberland village who was unable to pay the sum demanded for a letter from her brother in a distant county, relates an event which in principle may be repeated to-day in many parts of the world. A cheap telegraph service would unite families, however scattered, would keep the dispersed members in close and constant touch with the old home, and would cement friendships between our own people and the colonial nations, besides forging another link in the ties which bind this country to the United States."

Court Jek Ink.—The following recipe (British secret) furnishes an excellent ink, which is sold at a high price under the name of Court Jek (Court Ink?): Mix ground gall nuts 500 grammes, powdered gum arabic 80 grammes, powdered alum 36 grammes,

green vitriol 120 grammes, glycerine 36 grammes, log-wood 48 grammes, and 4 kilos of water. Boil for three quarters of an hour and filter. This ink can be copied.—Färber und Wäscher.

A REVIEW OF ALLOYS.*

THE ordinary method of obtaining alloys is by melting together the different constituents. However, alloys can also be obtained by subjecting the powders of the constituent metals to strong compression. It has furthermore been found that the molecules of metals penetrate each other when in contact, at temperatures far below the melting point of either of the constituents, some time to be alloyed with quantities of the above metals, the amount of which in the lead decreases with the distance from the plane of contact. That metallic alloys can be obtained by electro-deposition from their solutions is a well-known fact, but hardly applied otherwise than for purposes of electro-plating.

In combining different metals with each other, a few rules may be laid down regarding the qualities of the alloy, though it must be stated that, like most rules, they do not apply absolutely to every case. By adding one metal to another, the strength of the latter is generally increased up to a certain point dependent upon the nature of the metal added. After going beyond this limit, a decrease in strength takes place again, frequently very rapidly, unless the metal added possesses greater strength than the one to which it has been added. Tin, aluminium or zinc added to copper are examples of the correctness of this rule. By adding a third metal, not infrequently a further increase in strength can be accomplished. The hardness of a metal also generally increases by adding another metal. An alloy of 95 per cent copper and 5 per cent tin possesses double the hardness of pure copper. The ductility of metals is generally greater, the purer they are. The temperature is of some influence; copper and zinc are more ductile at a high temperature, while the ductility of brass and German silver decreases with a rise of temperature. The fusing point of a metal is generally lowered by alloying it with another. Alloying one metal with another in most cases decreases the conductivity for heat and electricity.

Copper and tin will unite to form homogeneous alloys in a wide range of proportions. As tin is added to pure copper the color of the alloy gradually changes, becoming decidedly yellow at 10 per cent, and turning to gray as the proportion approaches 30 per cent. In the researches conducted by the author, it was found that good alloys contain as much as 20 per cent tin. When the color changes from golden yellow to gray and white, the strength as suddenly diminishes; and alloys containing 25 per cent tin are valueless to the engineer; nevertheless, this alloy and those containing up to 30 per cent show compressive resistances increasing to a maximum. Under 17.5 per cent, the elastic limit lies between 50 and 60 per cent of the ultimate strength; beyond this percentage the proportion rises, and at 25 per cent tin the elastic limit and breaking point coincide. Passing 40 per cent tin this change is reversed and the elastic limit, although indefinite, is lowered until pure tin is reached and a minimum at about 30 per cent.

The bronzes useful to the engineer contain between 85 and 91 per cent copper and 15 to 9 per cent tin. A small addition of a deoxidizing agent like phosphorus, silicon, manganese, aluminium greatly increases the strength of a bronze. Copper and zinc together form brass, which is usually made nearly in the proportion copper 66 2-3, zinc 33 1-3.

Brass may be made tough or soft, hard or brittle, strong or weak, elastic or inelastic, dull of surface or lustrous as a mirror, friable or nearly as malleable and ductile as lead, as may be desired, by varying its composition. No known material, perhaps not even excepting iron, can be given so wide a range of quality or so wonderful a variety of uses. All the common varieties are composed of 67 to 70 parts copper and 33 to 30 of zinc. A little lead is often added to soften and cheapen it and tin in small proportion to strengthen it. The copper-tin-zinc alloys or kalchoids (from the Greek "kalchos," indicating bronze or brass) are of great value, and include the strongest and probably the hardest possible combinations. They are in most respects, usually, intermediate between the bronzes and the bronzes obtained by uniting two metals.

On making a large series of tests with compositions of the three metals named, Prof. Thurston finally arrived at the conclusion that the best alloys for purposes demanding toughness as well as strength lay between 58 and 54 per cent copper, 44 and 40 per cent zinc, and 2½ and ½ per cent tin. It was found that the strongest of bronzes contained 57 per cent copper, 1 per cent tin, and 42 per cent zinc; however, an alloy of the composition 56 per cent copper, 2 per cent tin, 42 per cent zinc is likely to prove more generally useful, in consequence of its greater ductility and resilience, and alloys with a little less tin may often prove better than that. The safest alloys under shock are those containing the smallest quantities of tin. By far the most ductile alloy of this series tested contained no tin at all and had the composition 57 per cent copper and 43 per cent zinc.

A discussion on the properties of alloys would be incomplete were the influence of small quantities of impurities upon metals not considered in this connection. We all know of the deleterious effect which small quantities of phosphorus and sulphur exert upon the quality of iron and steel. One-tenth of a per cent of antimony, bismuth or arsenic in copper or brass will make it absolutely impossible to roll these metals into sheets, due to their cracking under the rolls. The electrical conductivity of copper is materially diminished by minute quantities of impurities; on the other hand, it has been found by the "Alloys Research Committee" that a small quantity of arsenic is actually beneficial in copper used for fireboxes and staybolts. Two-tenths of a per cent of lead, bismuth or antimony

added to gold will make this most ductile of all metals so brittle that it can be shattered with the greatest of ease; a small quantity of arsenic in tin will transform this soft metal into a very hard and brittle one, etc.

I wish to add here a few observations made in my laboratory as regards the influence of small quantities of impurities upon the qualities of certain antifriction metals. A small quantity of zinc, from 5-100 to 1-10 of a per cent, in a lead-antimony-tin alloy, will greatly interfere with the obtaining of clean castings, due to the great tendency of forming oxides or drossing. A similar phenomenon is caused by the presence of 1-10 to 2-10 of a per cent of iron in a tin-copper-antimony alloy. A small quantity of arsenic in either of these alloys will cause large, lamellar and brittle crystals to be formed, which made the metals useless for the purposes they are intended for.

An attempt will now be made to show how considerations along lines as indicated above have contributed to our understanding of the nature of alloys. We all know that by dissolving common salt in water we lower the freezing point of the water. By increasing the amount of salt the freezing point of the resulting mixture is at first correspondingly lowered until it contains a certain percentage of salt. The lowest possible freezing point of a solution of salt in water is then reached and further addition of salt will gradually raise the freezing point of the brine. Dr. Guthrie found that the mixture which has the lowest possible freezing point contains about 23.5 per cent of salt. He proposed for it, and for all similar mixtures, i. e., for all saline solutions of lowest freezing points, the name of cryohydrate, by which he meant to imply that they can only exist in a solid state at low temperature.

The present theory of the constitution of alloys, worked out on the basis of the theory of solutions, ranges them into three classes: 1. Alloys which give neither definite compounds nor isomorphous mixtures. 2. Alloys which form definite compounds. 3. Alloys which form isomorphous mixtures. Into the first group belong the alloys of lead and antimony, lead and tin, copper and silver, etc.

Taking the curve of fusibility of antimony and lead as an example, we find that the lowest fusing point lies at 228 deg. C. with a composition of 13 per cent antimony and 87 per cent lead.

The similarity between this curve of fusibility and the curve of solubility of a saline solution is obvious. If a molten alloy of lead and antimony containing less than 13 per cent antimony is allowed to solidify slowly, lead will first start to crystallize out until the temperature has fallen to 228 deg. C., when the temperature will remain constant until the total mass of the alloy is solidified. If, on the other hand, more than 13 per cent of antimony is present in the alloy, the antimony will solidify first until on cooling to 228 deg. C. the lead and antimony will solidify together in the proportion of 87 to 13. From this may be easily observed the absolute similarity between the cryohydrate and the alloy of the lowest possible melting point, and for this latter Dr. Guthrie has proposed the name eutectic alloy.

Into the second group, alloys which form definite compounds, belong the tin-copper, antimony-copper, aluminium-gold, aluminium-antimony alloys and others.

In the case of alloys containing less than 25 per cent of copper, pure crystals of antimony are separated when solidification begins, increasing gradually in size as the temperature decreases; the portion remaining liquid, therefore, gradually becomes richer in copper until the composition of the eutectic alloy is reached; it then solidifies, at a constant temperature, through a simultaneous crystallization of antimony and SbCu. In the case of alloys containing from 25 to 60 per cent of copper, a similar phenomenon occurs, only it is the definite compound SbCu, which separates from the molten mass as soon as the freezing point is reached. When from 60 to 70 per cent of copper is present, the same compound is separated, but it is in this case surrounded by a second eutectic alloy made up of copper and the compound SbCu. Finally, when more than 70 per cent of copper is present, a portion of the latter is first deposited when solidification sets in, until the portion remaining liquid has reached the composition of the second eutectic alloy.

In the third group, alloys which form isomorphous mixtures, belong the alloys of silver and gold and of bismuth and antimony. The curve of fusibility of these alloys is the simplest imaginable, consisting merely of a straight line drawn between the two melting points of the respective metals.

In this case there is no eutectic alloy, as the whole mass solidifies at a constant temperature, which is a function of the composition.

All these conclusions drawn from the curves of fusibility have been corroborated by microscopic and analytical evidence, and a very large number of beautiful photomicrographs have been published by the above-named investigators. It might be mentioned in passing that the joint application of calorimetric and microscopic methods of investigation on iron and steel have contributed greatly to our understanding of the molecular constitution of these metals, the changes of the molecular arrangement on tempering, etc.

Bearing Metals.—A group of alloys of especial interest to the railroad man are the bearing metals. In 1892 Dr. Dudley published a report in which he condemned the use of gun bronze, quite generally employed in axle bearings at that time, and advocated the substitution of it by a bearing containing besides copper, tin and a small percentage of phosphorus, a quantity of 10 to 15 per cent lead, on the grounds that such an alloy was very much less liable to heating than cannon bronze and wore about 50 per cent less.

The conclusions he drew from a large number of tests were the following: 1. The loss of metal by wear under exactly the same conditions diminishes with the increase of lead. 2. The loss of metal by wear diminishes with the diminution of tin. 3. Phosphorus in a copper-tin-antimony alloy is more valuable in the foundry than in service. Its principal value lies in the help it gives in getting sound castings.

Dr. Dudley then proceeds to state that it is impossible to use white metal alloys for solid bearings, on account of the distortion they suffer in service due to

* Extracts from a paper presented before the April meeting of the Western Railway Club by Gustav Thurnauer, Ph.D., American Metal Company.