justified by comparing this effect with those obtained by experiments.

The evidence advanced in the preceding pages appears to the writer to confirm the conclusion that the whole subject of the corrosion of iron is an electrochemical one, which can be readily explained under the modern theory of solutions. It is an undeniable fact that some irons and steels suffer corrosion very much more rapidly than others, and the underlying causes for these differences constitute one of the important problems of modern metallurgy.

Although the discussions brought forward in this bulletin are mainly theoretical in their nature, it is quite apparent that they also have an indirect practical bearing. Before advance can be made in overcoming the difficulties in the way of manufacturing iron which shall have the maximum resistance to corrosion, as well as the preservation of the metal under the conditions of service, the underlying causes must be thoroughly understood. If we accept the electrochemical explanation of the corrosion of iron, there can be no doubt that conditions which inhibit electrolytic effects also inhibit corrosion, and *vice versa*. The purer the iron in respect to certain other metals which differ electro-chemically from iron and the more carefully lack of homogeneity and bad segregation are guarded against the less likely are the electrolytic effects to become serious. These points constitute the essential problems which confront the manufacturer who desires to make a product which shall have a high resistance to corrosion. The user and consumer, however, are interested in the protection of the various types of merchantable iron and steel which are available under market conditions at the present time. In short, protective coatings and palliative methods of treatment are in greater demand to-day than ever before. From the standpoint of the electrolytic theory many suggestions for experiment under the conditions of service present themselves. The fact that hydroxyl ions inhibit the rusting of iron has been made practical use of for a long time past, and it is not unusual to add caustic alkalis to boiler waters for this reason. This, however, frequently causes trouble from foaming and, as Cribb has shown, if an insufficient amount of alkali is present the pitting effect is accentuated rather than inhibited. This observation is in accord with the theory that the hydroxyl ions must reach a certain concentration, which varies with different conditions, before entire prohibition of the electrolytic effects is obtained.

At concentrations much below those necessary to prohibit electrolysis the action is similar to that obtained by adding a neutral electrolyte to the water, i. e., the electrolytic effects are localized if not stimulated. There should be many cases, however, where the property of alkalis to inhibit corrosion could be made of more practical use than has been done. Whenever iron posts or standards are set directly in the ground instead of being imbedded in concrete, the liberal use of slaked lime should be beneficial.

The expedient of using metallic zinc in boilers to overcome the local electrolytic effects in the iron by producing a still greater electrolytic effect at the almost exclusive expense of the more positive zinc is well known and has been in use for a long time. Although the theory on which the use of zinc for this purpose is based is sound, great difficulty has been encountered in maintaining good metallic contacts between sufficiently large surfaces of the two metals under the conditions which maintain in a boiler. From what has been shown in regard to the inhibitive action of the chromates it is not improbable, since such dilute solutions prevent electrolysis and corrosion, that the addition of small quantities of bichromate to boiler waters would be highly efficacious in preventing the rapid pitting which has caused so much trouble. It has lately been reported that steel boiler tubes used on vessels fitted with turbine engines suffered corrosion to the point of failure in from two to four months' service. This was found to be due to the fact that the steam, containing perhaps volatile acids, impinging on the bronze turbine blades, carried copper into solution and through the condensers into the boiler. Since iron does not change places with copper in dilute solution containing bichromate, it is possible that here again this salt would be found of practical value. That this statement is correct can easily be shown. If a bright piece of iron is immersed in a solution of copper sulphate so dilute as to show only a faint bluish tinge, the iron will nevertheless turn dark from precipitated copper in a very few moments. If, now, potassium bichromate is added in only just sufficient amount to give a yellowish instead of a bluish tinge to the solution, iron will remain bright and copper will not be deposited.

The experiment has been made by the writer of keeping iron and steel in dilute boiling solutions of bichromate for protracted periods at the same time that a current of air was bubbling through the boiler, and as long as the strength of the solution was equal to or above one one-hundred and-sixtieth normal no rusting has ever taken place. Since this strength is approximately equivalent to one pound of the salt in 1,500 gallons of water, there seems to be no reason why potassium bichromate should not come into use as a boiler protective. The application of the various inhibitors in the priming coats of paints and other protective coverings has already been to some extent made use of, and it would appear that slightly soluble chromates should be theoretically the best protectives for the first application to iron and steel surfaces.

A very widespread impression prevails that charcoal iron and puddled wrought iron are more resistant to corrosion than steel manufactured by the Bessemer and open-hearth processes. It is by no means certain that this is invariably the case, but it would follow from the electrolytic theory that in order to have the highest resistance to corrosion a metal should either be as free as possible from certain impurities, such as manganese, or should be so homogeneous as not to retain localized positive and negative nodes for a long time without change. Under the first condition the irons would seem to have the advantage, but under the second much would depend upon care exercised in manufacture, whatever process was used.

The evidence appears to be conclusive that the corrosion of iron in all its forms is primarily due to hydrogen ions. The ability of various samples to resist the attack of an acid of a standard strength may turn out to bear some relation to resistance to corrosion under service conditions. A great variation in resistance to acid corrosion is shown by different specimens of both iron and steel. An investigation of this subject is being made in conn ion with the work of Committee U of the American Society for Testing Materials. Carelessly made and poorly segregated metal will be easily attacked, no matter what it may be called or what method was used in its manufacture. As has already been pointed out, there are two lines of advance by which we may hope to meet the difficulties attendant upon rapid corrosion. One is by the manufacture of better metal, and the other is by the use of inhibitors and protective coverings. Although it is true that laboratory tests are frequently unsuccessful in imitating the conditions in service, it nevertheless appears that chromic acid and its salts should under certain circumstances come into use to inhibit extremely rapid corrosion by electrolysis and so tend to the preservation of iron.

DISTANT OPERATION BY HERTZIAN WAVES.

GARET'S APPARATUS.

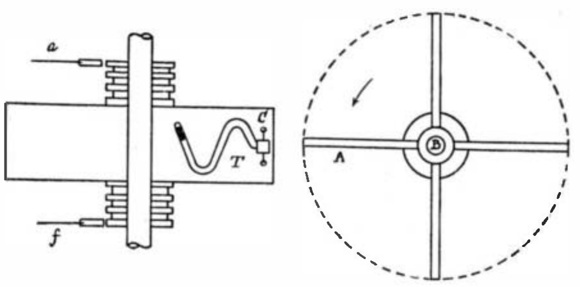
A FRENCH scientist, G. Garet, has invented an improved device for working a distant apparatus, as, for instance, a torpedo, by means of electric waves. It is asserted that the apparatus can be used to solve the difficult problem of distant mechanical operations carried on by aerial waves, and that it is also adapted for use on a wire circuit for the same purpose; likewise for railroad signals and many other devices. With a single wire it can carry out operations which now take as many as ten or fifteen different wires.

Referring to the diagram, the receiving apparatus is made up of a single wheel *A*, movable about a shaft *B*, and carrying a set of blades or disks in any number, each corresponding to a separate circuit in the device which is used, such as a torpedo. Each blade makes a contact when it comes to the proper point or brush for carrying the current. Such contacts carry out the propulsion, steering, etc., by means of motors or electromagnets placed in the different work circuits on the torpedo or other device.

The wheel is operated by a ratchet which turns it around. Each tooth of the ratchet is made to advance by a pawl worked by a relay. The relay is in the circuit of a coherer which receives the waves from the sending station (on land, for instance). Each wave signal causes the wheel to advance by one tooth, and in the present case by one blade as well. The operator can thus bring any given blade (corresponding to a work circuit which he wishes to put on) into the contact position by sending a set of short signals like the dots of the Morse alphabet.

What is peculiar to Mr. Garet's device lies in the fact that the blade can be brought into the contact position without having any of the other blades make a contact of any kind by their passage over the same point. Each blade carries a bent glass tube *T* with the air exhausted and containing a drop of mercury. In all the upper blades the mercury lies at the lower or inner end, but in the lower blades the mercury is at the outer end of the tube. There is one special position for each blade where the mercury leaves the center and moves to the periphery, and this is the position of contact, where the blade clears the horizontal position.

Each outer end of the tube carries an ebonite cap *C*, with two metallic points placed so that the mercury completes an electric circuit when at this point. When a blade comes into the contact position or angle the mercury does not at once reach the ebonite cap, but is delayed in a manner which can be well adjusted, since it depends on the slant and sinuosities of the tube, and this delay of contact gives the selection of the blade, since the operator can send signals which are spaced



DISTANT OPERATION BY HERTZIAN WAVES —RECEIVING DEVICE.

close enough together so that the drops have not time to reach the cap during the instant when the other blades pass by this special angle. When he ceases to send the signals the right blade has now come into place, and after a short time the mercury makes the contact desired. A properly placed commutator on the shaft gives the electric contact at *a* and *f*.

This retarding principle allows of controlling the working device (steering, etc.) A control or check signal shows the operator the exact moment when the right blade has come into the contact angle. In wireless operations this signal can be given from the torpedo, etc., by a transmitter lodged within it, or else a luminous signal can be used, which the operator sees. Since the speed of propagation is almost instantaneous, he is warned in advance that a certain circuit is about to be closed on the torpedo. If he desires to annul the operation which has been commenced, he sends an extra set of signals which causes the wheel to turn before the mercury arrives at the end of the tube, and the contact cannot therefore be made. Foreign wave signals which are not syntonized are obliged to use a certain time *t* of some length, in order to charge the coherer. It is known, in fact, that the coherer charge is equal to the product *C V t*. *V* being the potential, *C* the capacity, and *t* the time in seconds. As *C* and *V* are small, owing to the lack of syntonization, the factor *t* increases, and in practice it always has a value greater than the duration of the delay in the contact.—Western Electrician.

A NOVEL SYSTEM OF WIRELESS TELEPHONY.

IN a recent lecture before the Italian Society of Electrical Engineers, Prof. Q. Majorana of Rome describes his system of wireless telephony, which is based on the use of a spark gap, in which the intensity of the electric waves given off is altered in accordance with the sound vibrations striking the membrane of a microphone.

The rotating spark gap used by the professor comprises a motor, on the axle of which is mounted an ebonite disk, carrying, opposite one another, two metal rings, in contact with two metal brushes which are inserted in the discharge circuit. Two steel wires of 2 millimeters diameter are fixed to these rings and terminate in a piece of ebonite, insuring a rigid connection between either of them and one of the two terminal wires. The latter, like the other two wires, are parallel to one another; in order, however, that the discharge may occur between them, their distance has been made smaller. The two wires of the spark gap are connected to the secondary of a statical transformer, the primary of which is connected with the alternating current of the city mains.

Majorana uses an oil transformer capable of absorbing 2 kilowatts and of giving a maximum potential difference of 100,000 volts. In the present case the windings of this transformer are so arranged as to give a potential of only 25,000 volts.

When a convenient capacity (of about 0.0002 micr.) is inserted in the secondary circuit, as soon as the spark gap is rotated, the sparks, under the blowing action of the air, will be separated from one another, giving as many as 10,000 individual sparks per second.

The methods by means of which Majorana has acted on these sparks include the manometrical flame method and the methods of a vibrating wire in a magnetic field of gas or mercury jets respectively. The best results have, however, been obtained in connection with a method based on the use of a hydraulic microphone invented by Majorana himself.

In wireless telephony, microphones should obviously be liable to respond, not to an alteration in a low-tension current, as in the case of ordinary telephony, but to high-potential discharges, in connection with which a variable contact between carbon flames (as in the case of ordinary microphones) would obviously be without the least effect. The microphone invented by Majorana accordingly is susceptible to stand potential differences of several thousand volts without becoming heated under the action of intensive currents (several amperes).

Majorana's microphone is based on the well-known physical properties of liquid jets. The frequency of the individual drops into which a liquid jet is separated under the conditions of the experiment represent the period of the vibration of the jet. This can be observed by an acoustical method, causing the jet to strike an elastic membrane at the point where it begins to separate, which will give out a sound accurately corresponding to this period. If, however, outside vibrations strike the liquid jet, the latter will perform periodical contractions at a short distance from the mouth. These contractions strictly correspond to the period of the outside vibrations. The membrane accordingly gives out the sound corresponding to this period. If now a plane surface be inserted in the path of the jet at right angles to its direction, the jet will produce a liquid veil of variable thickness according to the vibrations of the jet.

The microphone based on these phenomena comprises, outside of the ordinary mouthpiece serving to concentrate the sound waves, a small glass tube traversed by slightly acidulated water free to move under the action of the vibrations of the membrane.

On issuing from an opening in this tube, the liquid will strike the plane surface of an attachment called a collector, consisting of two cylindrical platinum pieces insulated from each other by a solid insulator. On striking the center of this collector, the liquid jet will be converted into a thin veil, placing the two parts of the collector in permanent electrical connection. A telephone and battery inserted in the circuit of these collector parts will be traversed by a constant current as long as the membrane is not struck by sound vibrations coming from outside, that is to say, as long as the liquid jet does not undergo any contraction. As soon as outside sounds strike the vibrating membrane, the mouthpiece will, however, begin vibrating and the liquid jet will be contracted, corresponding to the sound vibrations. The intensity of the electric current will accordingly undergo periodical modification, resulting in the sounds and words spoken into the microphone being reproduced.

This microphone is inserted in the circuit producing the electro-magnetic waves, and when placed in suitable connection with the rotating spark gap, will serve to modify the intensity of the sparks in accordance with the sound waves and words enunciated before the microphone. These alterations will then reproduce the transmitted sounds at the detector of the receiving station with a perfect truthfulness.

The results obtained with this apparatus have been extremely satisfactory. Majorana has been using, also with good results, the hydrogen arc suggested by Poulsen, in the place of the rotating spark gap described above.

THE DEVELOPMENT OF ARMORED WAR VESSELS.—II.

ARMOR PLATING IN THE UNITED STATES.

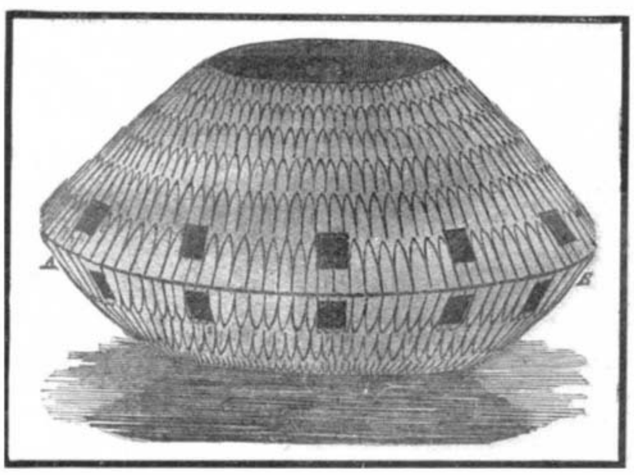
BY J. H. MORRISON.

Concluded from Supplement No. 1652, page 132.

THE most valuable paper on iron-clad ships of war at a very early date is considered to have been one written in 1823 by Capt. Montgery, an officer in the French navy. It was commented on by the London Mechanics Magazine in 1824 as follows: "Since the discovery by Mr. Perkins of so vast a destructive power as his steam artillery, it becomes of more importance than ever that nations should learn to make their ships as shot and shell proof as possible. On this subject there is in Ferusae's Bulletin des Sciences Technologiques a memorial of M. de Montgery, a captain in the French navy, which is well worth attention and from which we shall chiefly extract the materials of the present notice.

"The author's object is to recommend the universal adoption of iron instead of wood in the structure of ships. A multiplicity of objects formerly composed of wood are now formed of iron: bridges, arches, aqueducts for public highways, and other objects not so colossal, but very important in their application to maritime affairs, such as wrought-iron tanks and hollow cylinders for masts and yards, and chains in lieu of hempen cables and cordage. But why up to this time have there been so few vessels constructed entirely of iron? Will not mankind at some future period wonder how enlightened nations could have thought of building objects so stupendous and so expensive, with so fragile and so perishable a substance as wood, while they possessed a material to substitute for it so solid and durable as iron? The ordinary term of duration of wooden ships is twenty years; and during that period they must be hove down and thoroughly repaired three or four times. To the duration of an iron ship, on the contrary, it would be difficult to assign any period. Vessels of this description have no need of caulking or copper bottoming. Little subject to leaks, there is the less fear of their running ashore; and still less are they subject to the casualty of fire. The first cost of them might be greater—that we doubt; but from their far greater durability and standing so little in need of repairs the saving in the end would be immense. It deserves farther to be considered that large timber is becoming every day more and more scarce, while from the increased dimensions of new ships more wood is required in shipbuilding. Of iron, on the contrary, the stores are inexhaustible. It may be said that the adoption of iron would serve to uncraft or disqualify a numerous body of men (the shipwrights) and throw them for a time out of employment. A temporary inconvenience to a few ought not, however, to be opposed to a great, general good, considering, moreover, how much the country at large would gain by the increased activity which this new demand for iron would give to our mines, commerce, and agriculture.

"M. Montgery contends that while we have vessels of war constructed of wood, they should at least be plated with iron, and it will be seen from the following passage that he had distinctly anticipated such an application of projectile force as that discovered by Mr. Perkins: 'For more than 350 years it has been in agitation to throw shells from mortars *horizontally* instead of elevating them according to the general practice. The adoption of howitzers in the field of battle, independently of a great number of special experiments, has at length proved beyond doubt the importance of this mode of firing, which it has also been proposed to adopt on board of ships and on marine batteries. Long before anyone had thought of substituting metal for wood in the construction



W. SHIRES' STEAM ARMORED FLOATING CASTLE.

of large vessels' plates of iron or brass had been used for covering ships of war and battering rams. The celebrated galley built by Archytas and Archimedes for Hiero, tyrant of Syracuse, was cased in this way. Philo of Byzantium afterward proposed using battering machines made entirely of metal; but Father Mersenne appears to have been the first who thought of adopting them for ships.'

"M. Montgery says that to render the sides of a vessel shot and shell proof they should have a plating of iron about 6 inches thick; that is, a series of sheets of iron with blocks of cast iron between. He conceives that the blocks would only be necessary in the parts exposed to the fire of the enemy, and that there would be no occasion for them toward the keel of the vessel."

The first record found of an English proposal for a war vessel that was to be protected by iron is in the same mechanical journal, but of 1827, describing a "Floating Castle to go by steam, and to resist balls." The specifications of this proposal are: "The base of the castle is to be made of plank and to rest on flat-top boats, forming a common deck to them all, to which the boats are to be made fast. The side to be built in substance and quality like that of a man-of-war, and to be shielded with iron and steel plates. All the plates above the ridge to point upward, and those below it downward, so that they may deflect off all balls directed against the structure. The top is to be left open; but being above the horizontal range no ball can enter by it. The several steam engines and rudder by which the castle is to be conducted are to act within it through openings made in the bottom of the castle betwixt the boats; hence the acting part cannot be destroyed by shot. The lower guns are designed to fire at the hulls of ships, while the upper guns cut away the masts, rigging, etc. Castles thus made, each to cover an acre of ground, would carry ten thousand men with provisions for two months, and no doubt would be found better in practice than any other machine for a like purpose."—(Signed) W. SHIRES.

That the use of iron for the protection of wooden war vessels had not passed from the minds of American inventors at this time we have evidence of in the memorial presented to Congress in 1828 by Uriah Brown, of Baltimore, Md., "relative to a system of harbor and coast defence of the United States by means of impregnable and invincible fire ships." While this petition failed to be met with any action in its favor through legislation there were a few items of interest in the specifications of the vessel showing that iron plating had again been entertained by progressive men. The Secretary of the Navy in his report on the proposed vessel says in part: "The construction of the vessel of a sufficient thickness to render it impervious to the shot of an enemy, of a capacity to contain the whole machinery, with men, fuel, etc., and covered with sheet iron to prevent combustion, appears well calculated upon the principles of an inclined plane to reflect any shot at any possible angle at which they can be fired from a ship to be assailed." This proposed vessel was further described by a military expert of that day: "The plan of this vessel was predicated on the principle of inclined planes, and calculated to resist the shot of an enemy by reflecting them at any and every angle at which they might be directed by the ship to be assailed. The size of the vessel was calculated to be 125 feet in length and 50 feet in breadth, and to be propelled by steam power."

Even though there had been a desire in this country at this later period to design a vessel that should be protected with iron plate, it is altogether improbable that the plating could have been obtained in this country that would have been of good service for such a purpose, though it may have been obtained at the time, or a little later, from Great Britain. The subject appears to have gradually dropped from view, and it was several years before it came to be considered again of any moment. One of the reasons that may be assigned for this condition existing so many years would be that after 1824 when all barriers to the free navigation of the rivers of the United States were removed by the decision of the Supreme Court of the United States, a more extensive field was opened than had existed prior to that date for the inventive powers of those drawn to marine objects, and for several years the increase and improvements of our merchant marine occupied the best thought and talent of the country. The designing of labor-saving machines, the improvement of the old style of tools in our work shops, and the better methods devised of constructing a vessel, as well as building the machinery, claimed the attention of the American mechanic and the inventor for all these years. Their labors were expended in the development of the tools of a peaceful commerce, in place of designing improved types of engines of war for destruction. The country had enjoyed a long period of peace with all foreign