

I, which is made bulletproof, serves to cover the soldiers who are upon the bridge until it is judged proper to lower it in order to pass and to charge the enemy.

After this machine has been constructed and you desire to use it, you move it from one side of the canal to the other by means of the ropes, *K*, *L*, *M*, the pulley, *N*, and the capstan, *O*.

All the ropes being arranged as shown in the figure, the one marked *K* being attached by one end to an anchor fixed in the middle of the canal and the one marked *M*, which passes over the pulley, *N*, being attached to the end, *P*, of the bridge and wound around the capstan, the latter is revolved by manual power, and, in measure as it revolves and winds up the rope, *M*, it moves the bridge into the water and causes it to cross the canal.—From *Recueil d'Ouvrages Curieux de Mathematique et de Mecanique*, 1733.

ELECTROPLATING ON WOOD.

By C. F. BURGESS.

AN electrical industry of considerable importance is that which depends upon the deposition of metals from aqueous solutions of their salts by the electric current, for the purpose of imparting an ornamental or protective coating. The increasing uses which are being found for such coatings, and improvements in the processes for applying them, are contributing to a rapid growth of this industry.

This work is confined almost entirely to the deposition of a metal or alloy of metals on metallic surfaces, although the deposition of metals on non-conducting substances is practiced to a limited extent in such processes as the manufacture of parabolic reflectors, in which the metal is deposited on a prepared glass form, from which the coating is afterward removed, and in the production of electrotypes, which are made in a similar manner, wax instead of glass forming the mould. Most books treating of the electro-deposition of metals refer to methods for coating leaves, flowers, wood, and other non-conducting substances, and give various methods for so doing. These methods are usually so expensive and difficult of execution that they cannot be used extensively, though it is reported that in Germany the plating on wood has become an industry of some importance.

There is little question that, if an adhesive coating of metal could be easily and cheaply applied to wood and similar materials, a considerable demand for such work might be found. Designs carved in wood and coated with copper and brass would compete with the rather expensive copper, brass, and bronze castings used for ornamental purposes, and picture frames and mouldings could be given a true metallic surface instead of the metallic appearance which is usually imparted by means of metallic paints, which have little durability. The wooden handles of instruments such as are used by surgeons and dentists, when coated with nickel, would be both light and easily cleaned, without the annoyance of the handles becoming loose and cracking when subjected to alternate wetting and drying. Innumerable instances might be mentioned where a metallic surface is desirable, where great strength is not necessary and where lightness is advantageous, in which the electroplating process might find application.

The prime requisite for producing such a deposit electrolytically is that the body to be coated shall have a conducting surface, and it is with the formation of such surfaces that the various processes have to deal. After such surfaces have been obtained the electro-deposition is quite simple.

Electrotypers obtain such a surface by applying a conducting graphite to the wax mould, but such surfaces not only require considerable care in application, but they are not adhesive, which, of course, is desirable in that work, but would be a drawback if a permanent coating is required. The application of gold leaf and metallic powders is open to the same objection. An ideal coating would be one in which the fibers are thoroughly impregnated with a metal, and it is with the view of forming such a coating that the following processes are used.

As the metal in a liquid state cannot be absorbed by the wood, recourse must be had to the soluble salts of metals. By immersing the wood in solutions of such salts, the surface will become impregnated with the metal, which, however, is not in such a condition that it will conduct the electric current, for there are no chemical compounds which will offer sufficient conductivity for the purpose in view. The next step then is to change the metal into its elementary condition, which may be accomplished by a reduction process.

The usual method of recovering a metal from a compound is by the use of a reducing agent, such as carbon, in the presence of a high heat, but such process is prohibitive on account of the action of the heat on the wood surface. For this reason an easily reducible salt must be used, which will not require the application of a high temperature to effect the liberation of the metal; such salts being those of gold, silver, and platinum.

A typical process of such a nature is that which employs a solution made as follows: * 1.5 g. caoutchouc and 4 g. wax are dissolved in 10 g. carbon bisulphide, and this is mixed with solutions of 5 g. phosphorus in 60 g. carbon bisulphide and 4 g. powdered asphaltum in 5 g. turpentine. After immersing the wood in this solution and drying, it is dipped in a solution of 2 g. of silver nitrate in 600 g. water until the surface assumes a dark metallic appearance, and after rinsing in water it is finally dipped in a solution composed of 10 g. gold chloride in 600 g. water, after which it is ready to receive the electrolytic deposit.

A somewhat similar method is the employment of a solution of chloride of gold or platinum in sulphuric ether, to which a solution of sulphur in some heavy oil is added. On slightly heating this compound a sufficient consistency is attained to allow a film being laid on the surface to be plated. The object treated in this way is moderately heated in a muffle until sulphur and chlorine are completely volatilized, the gold or platinum adhering firmly to the surface.†

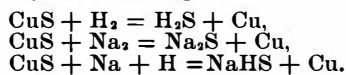
In a recent paper by Cowper-Cowles* on the electrolytic process for the manufacture of parabolic reflectors, a simple method is given for rendering glass surfaces conducting, which might possibly be applicable to surfaces of wood. It is as follows: The surface is dipped into a solution consisting of 0.5 per cent. of silver nitrate, 0.5 per cent. of caustic potash, and 0.25 per cent. glucose.

None of these methods have been tried by the writer, but it is quite evident that they have one or more of the following objections: expensive materials, danger to workmen, and time and care necessary for the operation. With the view of obtaining some process for obtaining this first metallic coating, which should be free from these objections, some work was carried on in the electro-chemical laboratory of the University of Wisconsin, and with quite satisfactory results.

The purpose was to employ materials less expensive than the silver and gold salts, and to effect the reduction by utilizing the reducing action at the cathode of the electrolytic cell. The intensity of the reducing action at the cathode depends upon various conditions, such as current density and nature of electrolyte, and is due to liberation of the materials which exist in the solution as the electro-positive ions. If a solution of a metal salt is used in which the metal is the positive ion, that metal will be deposited with a reasonably low current density, and little or no reducing action will occur. If the current density be increased so that hydrogen is liberated, or if a solution be used in which hydrogen is the positive ion, the well known reducing action of hydrogen may be noted. If a potassium or sodium salt be used in the electrolyte, the reducing action is much more marked.

The intensity of the reducing action at the cathode may be taken as approximately proportional to the amount of polarization at that electrode, when unattainable electrodes are used. Some measurements which were made to determine these values gave the following results. Employing carbon electrodes, the maximum cathode polarization was found to be, with NaCl, 1.00 volt; with NH₄Cl, 0.73 volt; with HCl, 0.32 volt; with KOH, 1.11 volt. These figures would indicate that the potassium and sodium salts are the best to use for the purpose in view, and this was confirmed upon trial.

The following is a description of the process by means of which a metallic surface on wood and other non-conducting materials has been obtained. The wood is first immersed in a saturated solution of copper sulphate, and then thoroughly dried, leaving the pores of the surface filled with copper sulphate. On exposing to the action of hydrogen sulphide gas, or immersing it in an aqueous solution of that gas, the copper in the sulphate is changed to copper sulphide. A copper conducting wire of small diameter is then wrapped uniformly around the object, so that each portion of the surface shall be within about one-half inch of the copper conductor, and it is suspended as a cathode in a solution of common salt (NaCl). A current density of a rather high value is used, and the cathode products will decompose the copper sulphide, the action being represented by the following formulæ:



Metallic copper is thus set free. This coating is black and without a metallic appearance, but it conducts the current as desired. It forms first at the points of contact of the wire and the wood and gradually spreads over the entire surface, the time necessary for this operation being about ten minutes, using the proper solution and current density. The object may then be transferred to the copper sulphate or other plating bath, where a coating to any desired thickness may be obtained.

The coating thus formed will be an exact reproduction of the surface of the wood, the grain being clearly shown, and will be sufficiently adhesive to stand grinding and burnishing.

The purpose of transforming from copper sulphate to the sulphide is to render the salt insoluble in water. Otherwise, on placing the article in the bath of sodium chloride, the copper sulphate would be redissolved and no continuous coating could be formed. The copper sulphide, on the contrary, is quite insoluble, and it is also more easily reduced to the metallic state.

Copper compounds are preferable to similar compounds of the other common metals, owing to the high conductivity of copper and the less stable compounds which it forms.

In the process just described a separate bath is used for the reduction of the sulphide, but this may be just as readily accomplished in some metallic bath where the metal is deposited simultaneously with the reduction of the sulphide. A potassium copper cyanide solution is such a one that the processes of reduction of the copper sulphide and the deposition of the metal from the solution may be carried on simultaneously, for here the potassium forms the electro-positive ion, while the CuCy₂ is the negative. The copper is deposited by a secondary reaction.

A solution of silver nitrate used in place of the copper sulphate will enable the process to be carried on more rapidly, though the greater cost of the silver salt is a disadvantage.

If the material to be plated is one which will expand on absorbing moisture, it will do so when placed in the plating bath. Consequently, after it has received its metallic coating, upon drying it will contract and thus cause the coating to wrinkle up and become loose. This may be avoided by leaving the object in the bath for only a short time; then drying it, and repeating the process until the desired thickness is obtained. Or, the following process, which I have used satisfactorily, may be employed:

The wood is first immersed in hot paraffin, which it readily absorbs, and is thus rendered impervious to moisture. It is then placed in gasoline, which dissolves the paraffin near the surface and renders it capable of absorbing the metallic salt. The trouble caused by expansion is thus entirely removed.

By the above process articles of wood, vulcanized fiber, and hard rubber have been given firm, adhesive coatings of copper, nickel, zinc, silver, etc., which were capable of being polished as readily as though de-

posited on metallic surfaces, and the process appears to be one which might readily be put to commercial use. It at any rate shows one of the many ways in which the oxidizing and reducing actions which take place at the electrodes of an electrolytic cell may be put to a practical use.—The Electrical World.

[Continued from SUPPLEMENT, No. 1189, page 19069.]

INAUGURAL ADDRESS BY SIR WILLIAM CROOKES, F. R. S., V. P. C. S., PRESIDENT OF THE BRITISH ASSOCIATION.

FURTHER prosecution of these researches must lead to deeper insight into molecular processes and the mode in which they affect the ether; indeed, already valuable theoretic views have been promulgated by H. A. Lorenz, J. Larmor, and G. F. Fitzgerald, on the lines of the radiation theory of Dr. Johnstone Stoney; and the connection of the new phenomena with the old magnetic rotation of Faraday is under discussion. It is interesting to note that Faraday and a number of more recent experimenters were led by theoretic considerations to look for some such effect; and though the inadequate means at their disposal did not lead to success, nevertheless a first dim glimpse of the phenomenon was obtained by M. Fizeau, of the Royal Observatory at Brussels, in 1885.

It would be improper to pass without at least brief mention the remarkable series of theoretic papers by Dr. J. Larmor, published by the Royal Society, on the relationship between ether and matter. By the time these researches become generally intelligible they may be found to constitute a considerable step toward the further mathematical analysis and interpretation of the physical universe on the lines initiated by Newton.

In the mechanical construction of Roentgen ray tubes I can record a few advances; the most successful being the adoption of Prof. Silvanus P. Thompson's suggestion of using for the antikathode a metal of high atomic weight. Osmium and iridium have been used with advantage, and osmium anti-kathode tubes are now a regular article of manufacture. As long ago as June, 1896, X-ray tubes with metallic uranium antikathodes were made in my own laboratory, and were found to work better than those with platinum. The difficulty of procuring metallic uranium prevented these experiments from being continued. Thorium anti-kathodes have also been tried.

Roentgen has drawn fresh attention to a fact very early observed by English experimenters—that of the non-homogeneity of the rays and the dependence of their penetrating power on the degree of vacuum; rays generated in high vacua have more penetrative power than when the vacuum is less high. These facts are familiar to all who have exhausted focus tubes on their own pumps. Roentgen suggests a convenient phraseology; he calls a low vacuum tube, which does not emit the highly penetrating rays, a "soft" tube, and a tube in which the exhaustion has been pushed to an extreme degree, in which highly penetrating rays predominate, a "hard" tube. Using a "hard" tube, he took a photograph of a double barreled rifle, and showed not only the leaden bullets within the steel barrels, but even the wads and the charges.

Benoit has re-examined the alleged relation between density and opacity to the rays, and finds certain discrepancies. Thus, the opacity of equal thicknesses of palladium and platinum are nearly equal, while their densities and atomic weights are very different, those of palladium being about half those of platinum.

At the last meeting of the British Association visitors saw—at the McGill University—Profs. Cox and Callendar's apparatus for measuring the velocity of Roentgen rays. They found it to be certainly greater than 200 kilometers per second. Majorana has made an independent determination, and finds the velocity to be 600 kilometers per second with an inferior limit certainly of not less than 150 kilometers per second. It may be remembered that J. J. Thomson has found for kathode rays a velocity of more than 10,000 kilometers per second, and it is extremely unlikely that the velocity of Roentgen rays will prove to be less.

Trowbridge has verified the fact, previously announced by Prof. S. P. Thompson, that fluor spar which by prolonged heating has lost its power of luminescing, when reheated regains the power of thermoluminescence when exposed to Roentgen rays. He finds that this restoration is also effected by exposure to the electric glow discharge, but not by exposure to ultraviolet light. The difference is suggestive.

As for the action of Roentgen rays on bacteria, often asserted and often denied, the latest statement by Dr. H. Rieder, of Munich, is to the effect that bacteria are killed by the discharge from "hard" tubes. Whether the observation will lead to results of pathologic importance remains to be seen. The circumstance that the normal retina of the eye is slightly sensitive to the rays is confirmed by Dorn and by Roentgen himself.

The essential wave nature of the Roentgen rays appears to be confirmed by the fact ascertained by several of our great mathematical physicists, that light of excessively short wave length would be but slightly absorbed by ordinary material media, and would not in the ordinary sense be refracted at all. In fact, a theoretic basis for a comprehension of the Roentgen rays had been propounded before the rays were discovered. At the Liverpool meeting of the British Association, several speakers, headed by Sir George Stokes, expressed their conviction that the disturbed electric field caused by the sudden stoppage of the motion of an electrically charged atom yielded the true explanation of the phenomena extraneous to the Crookes high vacuum tubes—phenomena so excellently elaborated by Lenard and by Roentgen. More recently, Sir George Stokes has restated his "pulse" theory, and fortified it with arguments which have an important bearing on the whole theory of the refraction of light. He still holds to their essentially transverse nature, in spite of the absence of polarization, an absence once more confirmed by the careful experiments of Dr. L. Graetz. The details of this theory are in process of elaboration by Prof. J. J. Thomson.

Meantime, while the general opinion of physicists seems to be settling toward a wave or ether theory for the Roentgen rays, an opposite drift is apparent with respect to the physical nature of the kathode rays; it

* *L'Electricien*, vol. xii., 1896, p. 208.

† *London Electrician*, 1888, p. 110.

* *Jour. Inst. Elec. Eng.*, March, 1898.