

ator. We shall postpone the consideration of the artificial coloring to some more convenient time. For the production of the silver bronzes—the aluminium, genuine gold and silver bronzes—we do not begin with the bullion itself, but the respective metals are cast into bars, rolled into strips, cut in small squares, and beaten in forms, just like leaf metal, with the hand. The material thus obtained is then ground in the same mills as the gold bronze powder, made finer in the “steig” mills, and run through other mills and chasers for finishing.

We give below further directions for the making of metallic powders. To produce a bronze powder of the color of brass, we proceed as follows: Subject the ordinary zinc dust of commerce, first of all, to a thorough chemical or mechanical cleansing, for the purpose of removing to the utmost degree any active oxidizing agents. Immerse it then in a brass-plating bath, consisting of an ammoniacal solution of cupric and zinc cyanide, in proportions to suit, according as one desires a more or less red or yellow tone.

The compositions of such brass-plating baths are well known. It is mainly important to keep the particles in the bath in an even and constant motion, which is best effected by the application of some mechanical means of stirring.

From time to time test samples must be taken out, in order to determine the thickness and quality of the coating. This is shown either by rubbing the powder upon a piece of glass with the polishing iron, or subjecting it to treatment with an acid solution of known concentration, in order to learn of what resistance the coating is capable. Having become satisfied that the thickness of the enveloping shell is sufficient, the product must be washed several times in water and dried. Should the zinc powder have been previously polished by mechanical means, only a very slight polishing will be needed by the product prepared as above; if, on the contrary, the powder shall have been cleansed only chemically, then it must be subjected to the bath as above detailed, and still stands in need of a severe polishing in the polishing mill or in any other suitable and convenient way.

In a similar manner, through the employment of other metallic baths, a whole series of different-colored metallic powders may be produced, of which the inner core consists of zinc covered by a shell or envelope of any electro-positive metal whatever. Moreover, it is also possible to impart to the envelope, by a second treatment, either electrolytically or by the annealing process, any desired tint or color, as we have done with the ordinary bronze-color powders.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Der Stein der Weisen.

THE ARTIFICIAL PRODUCTION OF RUBIES.

To the numerous experiments in synthesis, conducted either by dry or wet processes, which permitted Ebelmen, de Senarmont, Sainte-Claire-Deville, Hautefeuille, Frey, Verneuil, and others to reproduce corundum, there has been recently added a new method that has the advantage over the preceding of affording stones capable of being employed in jewelry. We give here the broad lines of this method, which is to be published in the *Annales de Chimie et de Physique* with all the details that are necessary to permit the jewelry industry making use of it.

The inventor of this new process, which consists in first fusing the ruby by means of the oxyhydrogen blowpipe and then crystallizing it slowly in order to cause it to preserve its transparency, established the fact by his preliminary researches that the conditions that should be realized in order to permit of obtaining transparent crystallized rubies by fusion may be briefly summed up thus: (1) The fusion should be effected by always utilizing that part of the flame which is richest in hydrogen and carbon in order to prevent a bubbling that would interfere with the perfect refining; (2) the increase of the mass should be produced by layers superposed from the bottom upwardly, in order to effect the refining upon a series of thin layers, and also to effect a gradual solidification that shall allow the product to remain transparent; (3) the fusion should be effected under conditions such that the contact of the fused product with the support shall be limited to an extremely small surface, in order to reduce to a minimum the number of fractures, which become subdivided and render the product non-utilizable when the surface of contact of the molten ruby with every wall is not reduced to one point.

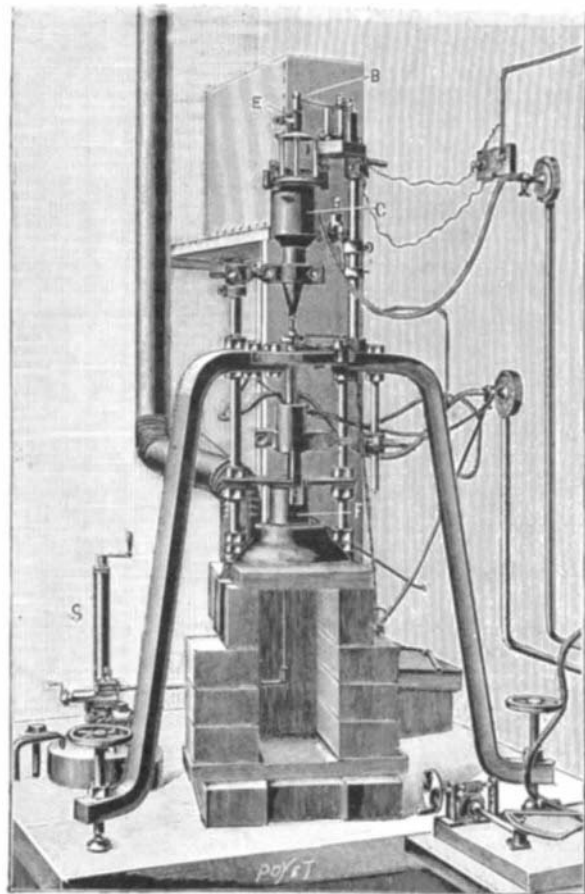
These three conditions are obtained by means of an apparatus of which a general view is given in the accompanying figure. In this figure, the screw support, S, to the left, permits of moving the molten mass to a distance by lowering it in measure as the proper zone of fusion becomes more distant from the end of the blowpipe, and when, during the course of the work, it becomes necessary to increase the pressure of the oxygen in the apparatus.

The refining by successive thin layers is obtained by means of a process that constitutes the most original part of the method, and which consists in drawing the powder of alumina mixed with oxide of chromium, or else the pulverized natural ruby, designed to be submitted to fusion, into the current of oxygen that supplies the blow-pipe.

These materials, contained in a wire-cloth basket placed in the chamber, C, are sifted by the slight impacts of the hammer, B, upon the anvil, E, that forms the top of the basket; and the powder, carried along in the central tube of the blow-pipe, becomes dis-

tributed through the flame and undergoes fusion therein as soon as it reaches a support formed of a thin stick of alumina placed in the center of the furnace, F. This powder, falling upon the alumina previously raised to a white heat, becomes agglomerated thereon, forming a cone, the point of which gradually rises until it reaches a zone of the flame hot enough to cause it to undergo fusion and form a filament that realizes the third condition enunciated above. If, now, the pressure of the oxygen be increased, this filament will be converted at its apex into a sphere, the diameter of which it will suffice gradually to increase up to the extreme limits that the heat of the blow-pipe is capable of reaching. Under such conditions, it is possible in three hours, by means of a blow-pipe with a nozzle 2.2 millimeters in diameter, to produce an ovoid mass of from 2 to 3 grammes' weight (say from 10 to 15 carats), which divides exactly into two parts, according to a vertical plane, when the primitive point is sufficiently fine and the mass in fusion has been very regularly heated. Each of these parts may be now cut according to the ordinary processes employed by lapidaries.

The chemical properties of these rubies are evidently identical with those of natural ones, their composition is the same, and they present the same resistance to reagents. When they are examined from a physical viewpoint, it is found that their magnificent red fluorescence is identical with that exhibited by the natural stone. They exhibit also the same luminescence when they are brayed or are submitted to energetic friction. Their density, which confirms the identity, is 4.01. Their hardness, estimated by their resistance to wear on the emery or diamond wheel, has been found to be identical with that of natural



APPARATUS FOR THE PRODUCTION OF RUBIES BY FUSION.

rubies by all lapidaries who have examined them. Such hardness, moreover, is shown by the very beautiful polish that they take after they have been cut upon the tripoli wheel.

Finally, their color equals that of the finest rubies of the East, when the alumina employed has been carefully purified and the chromium oxide has been properly proportioned. A crystallographic study of these artificial rubies also demonstrates the identity of their structure with that of the natural stones, and, as regards their optical properties, not a fragment of one of them could be distinguished from a stone cut from a natural crystal. It results from this that, from a chemical, physical, and crystallographic standpoint, there is an identity of properties and molecular structure between the artificial and natural ruby, and that this process of fusion, from a scientific viewpoint, affords a true synthesis of the stone under consideration.

But the identity of the natural product no longer exists as a general thing when the examination is directed to a mass of several carats instead of to an exceptionally selected parcel. In fact, it is but rarely that it has been possible to obtain stones that, after being cut, weighed a quarter of a carat, and that were entirely free from the two defects that up to the present characterize artificial rubies. These two defects, which are especially sensible in the large stones, consist of fine bubbles that are visible in the microscope and of striae of discoloration due to a volatilization of the chromium oxide when the operation has not been sufficiently regular. But it is very probable that by making use of more powerful and perfect apparatus it will soon be possible to produce homogeneous rubies of several carats' weight, while up to the present none has been obtained weighing more than a grain. It is

well to add that although the two defects already mentioned may allow experts to recognize the artificial rubies, the bubbles and striae, which are visible only upon a scientific examination, in nowise detract anything from the luster and beauty of these artificial stones when the latter are the result of a well-conducted manufacture. In reality, such defects are imperceptible when the mounted rubies are examined under ordinary conditions and at some distance; and the limpidity of the latter by far exceeds the average transparency exhibited by the natural striae, which also exist but very rarely in a perfect state. There is, therefore, reason to hope that after these artificial rubies come to be appreciated at their just value, the researches under consideration will put within reach of most people a stone as beautiful and durable as the natural ruby itself, which has hitherto been reserved for a privileged few.—Translated from *La Nature* for the SCIENTIFIC AMERICAN SUPPLEMENT.

THE STEEL HARDENING METALS.*

By JOSEPH HYDE PRATT.

THERE are included under the head of steel-hardening metals, nickel and cobalt, chromium, tungsten, molybdenum, vanadium, titanium, and uranium, which are named in the order of the importance of their production and use for steel-hardening purposes.

The special steels resulting from these additions vary among themselves, having individual properties of tensile strength and elastic limit, of conductivity, heat and electricity, of magnetic capacity and of resistance to impact, whether as shell or as armor plate. It was only about twenty years ago that the first of these metals, nickel, began to be used to any extent for the purpose of hardening steel, but since their introduction their use for this purpose has continued to increase steadily. Experiments are still being carried on with some of these metals in order to determine their actual commercial value with regard to the qualities that they impart to steel. In the arts it is the ferro-alloy of these various metals that is first prepared and is then introduced in the required quantity into the manufactured steel, but this ferro-alloy is never added to the molten mass during the manufacture of the steel. All these metals give characteristic and distinct properties to steel, but in all cases the principal quality is the increase in the hardness and the toughness of the resulting steel. Some of the metals, as nickel, chromium, and tungsten, are now entirely beyond the experimental stage and are well established in the commercial world as definite steel-hardening metals, and new uses are being constantly devised for the different steels, which are causing a constant increase in their production. Others, as molybdenum and vanadium, though they have been proved to give certain positive values to steel, have not been utilized to any large extent as yet in the manufacture of molybdenum or vanadium steel, partly on account of the high cost of the ores containing these metals. Titanium and uranium are still in the experimental stage; and, although a good deal has been written as to the value of titanium as an alloy with steel, there is at the present time very little if any of it used in the manufacture of a commercial steel.

Since the introduction of the electric furnace and the consequent methods that have been devised for reducing ores, it has become possible to obtain these ferro-alloys directly from the ores by reducing them in the electric furnace, and hence experiments have been conducted on a much larger scale than formerly.

MANGANESE STEEL.

Besides the use of ferromanganese for the chemical effect which it produces in the manufacture of steel in eliminating injurious substances, it is also used in the production of a special steel which possesses to a considerable degree combined hardness and toughness. Such steel contains from 0.8 to 1¼ per cent of carbon and about 12 per cent of manganese and is known as “Hadfield manganese steel.” If only 1.5 per cent of manganese is added, the steel is very brittle, and the further addition increases this brittleness until the quantity of manganese has reached 4 to 5.5 per cent, when the steel can be pulverized under the hammer. With a further increase, however, of the quantity of manganese, the steel becomes ductile and very hard, reaching its maximum degree of these qualities with 12 per cent of manganese. The ductility of the steel is brought out by sudden cooling, a process the opposite of that used for carbon steel. These properties of manganese steel make it especially adapted for use in the manufacture of rock-crushing machinery, safes, and mine car wheels.

NICKEL STEEL.

Nickel finds its largest use in the manufacture of special nickel and nickel-chromium steels, and the use of these steels for various purposes in the arts is constantly increasing. The greatest quantity of nickel steel is used in the manufacture of armor plate, either with or without the addition of chromium. There is probably no armor or protective deck-plate made which does not contain from 3 up to 5 per cent of nickel. Nickel steel is also used for the manufacture of ammunition hoists, communication tubes, and turrets on battleships, and for gun shields and armor.

The properties of nickel steel or nickel-chromium steel that make it especially adapted for these purposes are its hardness and great tensile strength, combined with great ductility and a very high limit of elasticity. One of the strongest points in favor of a

* From a paper in “Mineral Resources of the United States,” issued by the U. S. Geological Survey, 1904.

nickel steel armor plate is that when it is perforated by a projectile it does not crack. The Krupp steel, which represents in composition about the universal armor-plate steel, contains, approximately, 3.5 per cent of nickel, 1.5 per cent of chromium, and 0.25 per cent of carbon.

Another use for nickel steel that is gradually increasing is the manufacture of nickel steel rails. During 1903 there were over 11,000 tons of these rails manufactured, which were used by the Pennsylvania, the Baltimore & Ohio, the New York Central, the Bessemer & Lake Erie, the Erie, and the Chesapeake & Ohio railroads. These orders for nickel steel rails resulted from the comparison of nickel steel and carbon-steel rails in their resistance to wear during the five months' trial of the nickel steel rails that were used on the Horseshoe Curve of the Pennsylvania Railroad. The advantages that are claimed for the nickel steel rail are its increased resistance to abrasion and its higher elastic limit, which increases the value of the rail as a girder. On sharp curves it has been estimated that a nickel steel rail will outlast four ordinary rails.

Nickel steel has also been largely adopted for forgings in large engines, particularly marine engines, and it is understood that this is now the standard material for this purpose in the United States navy. There is a very great variety of these forgings and drop forgings, which include the axle and certain other parts of automobiles, shafting and crankshafts for government and merchant marine engines and stationary engines, for locomotive forgings, the last including axles, connecting rods, piston-rods, crank-pins, link-pins, and pedestal cap bolts, and for sea-water pumps.

Another important application that is being tried with nickel steel is in the manufacture of wire cables, and during the last year such cables have been made by the American Steel and Wire Company, but no comparison can as yet be made between them and the ordinary carbon-steel cables with respect to their wearing qualities.

In the manufacture of electrical apparatus nickel steel is beginning to be used in considerable quantity. The properties of this steel which make it especially valuable for such uses are, first, its high tensile strength and elastic limit, and, second, its high permeability at high inductions. Thus steel containing from 3 to 4 per cent of nickel has a lower permeability at low inductions than a steel without the nickel, but at the higher inductions the permeability is higher. A notable instance of the use of this material is in the field rings of the 5,000-horse-power generators built by the Westinghouse Electric and Manufacturing Company for the Niagara Falls Power Company. These field rings require very high tensile strength and elastic limit, and in order to reduce the quantity it is desirable that they have high permeability at high inductions. This result was secured by using a nickel steel containing approximately 3.75 per cent of nickel. Steel containing approximately 25 per cent of nickel is non-magnetic and has a very low resistance temperature coefficient. This property is occasionally of value where a non-magnetic material of very high tensile strength is required. The high electrical resistance of nickel steel of this quality, together with its low-temperature coefficient, makes it valuable for electrical resistance work where a small change in the resistance due to change in temperature is desirable. The main objection to using nickel steel for this purpose is the mechanical defects that are often found in wire that is drawn for this quality of nickel steel.

For rock drills and other rock-working machinery nickel steel is used in the manufacture of the forgings which are subjected to repeated and violent shocks. The nickel content of the steel used in these forgings is approximately 3 per cent, with about 0.40 per cent of carbon. The rock drills or bits are made for the most part of ordinary crucible cast steel which has been hardened and tempered. There is a field for investigation here in respect to the value of some of the special drills in the manufacture of rock-drill steels or bits. A nickel-chrome steel is now being made which is used to some extent in the manufacture of tools.

Nickel steel in the form of wire has been used quite extensively and for many purposes—for wet mines, torpedo defense netting, electric lamp wire, umbrella wire, corset wire, etc.—where a non-corrosive wire is especially desired. When a low coefficient of expansion is desired—as in the manufacture of armored glass, in the mounting of lenses, mirrors, lever tubes, balances for clocks, weighing machines, etc.—nickel steel gives good satisfaction. For special springs, both in the form of wire and flats, a high carbon nickel steel has been introduced to a considerable extent. Nickel steel is also being used in the manufacture of dies and shoes for stamp mills, for cutlery, table ware, harness mountings, etc.

Nickel steels containing from 25 to 30 per cent nickel are used abroad to some considerable extent for boiler and condenser tubes and are now being introduced into this country. The striking characteristic of these steels is their resistance to corrosion either by fresh, salt, or acid waters, by heat, and by superheated steam. The first commercial manufacture of high nickel-steel tubes began in France in 1898, and was followed in Germany in 1899; but it was not until February, 1903, that these tubes were made in the United States. Since then, however, Mr. Albert Ladd Colby states:

"The difficulties of their manufacture have been so thoroughly overcome that the 30 per cent nickel steel, seamless, cold-drawn marine boiler tubes, now a commercial proposition, are made in practically the same

number of operations, and with but a slightly greater percentage of discard than customary in the manufacture of ordinary seamless tubes, and, furthermore, the finished 30 per cent nickel tube will stand all the manipulating tests contained in the specifications of the Bureau of Steam Engineering, United States Navy Department, for the acceptance of the carbon-steel seamless cold-drawn marine boiler tubes now in use. In addition, the nickel-steel tubes have a much greater tensile strength."

Although the first cost of the nickel-steel tubes for marine boilers is considerably in excess of the carbon-steel tubes, yet, on account of the longer life of the nickel-steel tubes, they are in the end cheaper than the others. At the present time 30 per cent nickel-steel tubes cost from 35 cents to 40 cents per pound, as compared with 12 cents to 15 cents per pound for the corresponding mild carbon-steel tubes. Thus their initial cost, when used in the boilers of torpedo boat destroyers, is 2.13 times as great as the other kind and 2.43 times as great when used in the boilers of battleships, but the nickel-steel tubes will last two and one-third times longer than those made of the carbon steel, and when finally taken from the boilers they can be sold not only for the market price of steel-tubing scrap, but also at an additional price of 20 cents per pound for their nickel content. Thus it is seen that 30 per cent nickel-steel boiler tubes are really more economical to purchase than carbon-steel boiler tubes.

In addition to marine boilers, high nickel-steel tubes can be used to advantage for stationary boilers, automatic boilers, and locomotive safe ends. It is the higher elastic limit of the 30 per cent nickel-steel boiler tubing that will prevent the leaks that are constantly being formed where the mild carbon-steel tube is used. The leaks are due to the expansion of the flue-sheets when heated, which compress the tubes at the points where they pass through the fluesheets, and cause in the case of the mild carbon-steel tube a permanent deformation. This results in the leakage and necessitates the frequent expanding of the tubes. In the high nickel-steel tubes this difficulty is overcome by their higher elastic limit. This deformation and the resulting leakage are especially true of locomotive boilers. For automobile tubular boilers a 23 to 25 per cent nickel-steel tubing is used, each coiled section being made from one long piece of nickel-steel tubing, which, by a special heat treatment, is enabled to withstand this bending without cracking.

Nickel-steel tubing containing 12 per cent of nickel has been used by the French since 1898 in the manufacture of axles, brake beams, and carriage transoms for field artillery wagons, and the desired result in the reduction of weight has been obtained without loss and without stiffness of the wagons. A 5 per cent nickel-steel tubing has been used in the manufacture of bicycles since 1896.

CHROMIUM STEEL.

The largest use of chromium is in the manufacture of a ferro-chromium alloy which is used in the manufacture of a chrome steel. In the manufacture of armor plate ferro-chrome plays a very important part, and, although it is sometimes used alone for giving toughness and hardness to the armor plate, it is more commonly used in combination with nickel, making a nickel-chromium-steel armor plate. Other uses of chrome steel are in connection with five-ply welded chrome steel and iron plates for burglar-proof vaults, safes, etc., and for castings that are to be subjected to unusually severe service, such as battery shoes and dies, wearing plates for stone crushers, etc. A higher chromium steel which is free from manganese will resist oxidation and the corrosive action of steam, fire, water, etc., to a considerable extent, and these properties make it valuable in the manufacture of boiler tubes. Chromium steel is also used to some extent as a tool steel, but for high-speed tools it is being largely replaced by tungsten steel, which seems to be especially adapted to this purpose.

The percentage of chromium that is used in the chromium steels varies from 2.5 to about 5 per cent and the carbon from 0.8 to 2 per cent. The hardness, toughness and stiffness which are obtained in chromium steel are very essential qualities, and are what make this steel especially beneficial for the manufacture of armor-piercing projectiles as well as of armor plate. For projectiles chromium steel has thus far given better satisfaction than any of the other special steels, and is practically the only steel that is used for this purpose. The value of chromium steel for this purpose is well brought out by Mr. R. A. Hadfield, manager of the Hecla Works, Sheffield, England, who states that a 6-inch armor-piercing shot made by this firm was fired at a 9-inch compound plate, which it perforated unbroken. It was then fired again from the same gun and perforated a second plate of the same thickness, the shot still remaining unbroken.

TUNGSTEN STEEL.

Tungsten steel is used to some extent more generally abroad than in the United States, in the manufacture of armor plate and armor-piercing projectiles. For this purpose it is used in combination either with nickel or chromium, or with both of these metals. The use for which tungsten steel seems to be best adapted is in the manufacture of high-speed tools and magnet steels. The property that tungsten imparts to the steel is that of hardening in the air after forging and without recourse to the usual methods of tempering, such as immersion in oil, water, or some special solution. For high-speed tools tungsten steel is especially adapted, as it retains its hardness and cutting edge even at the temperature developed in the use of these

high-speed tools. The value of tungsten steel for permanent magnets is on account of its retaining comparatively strong magnetism and of the permanence of this magnetism in the steel. This property makes the tungsten steel particularly desirable in instrument work where the calibration of the instrument depends upon the permanence of the magnet used. For compass needles tungsten steel has been used by W. and L. E. Gurley with entire satisfaction.

MOLYBDENUM.

The use of molybdenum steel continues to increase, and hence there is an increasing demand for the ores of this metal. The main use of ferromolybdenum is in the manufacture of tool steel. The properties which molybdenum gives to steel are very similar to those given by tungsten, the main difference being that it requires a smaller quantity of molybdenum than of tungsten to acquire the same results. Ferromolybdenum is produced, like ferrotungsten, by reducing it from the ore in an electric furnace. There are now two molybdenum-nickel alloys being produced, one of which contains 75 per cent molybdenum and 25 per cent nickel, and the other 50 per cent molybdenum and 50 per cent nickel. Besides these constituents the alloy contains from 2 to 2.5 per cent iron, 1 to 1.5 per cent carbon, and 0.25 to 0.50 per cent silicon. The molybdenum steel which is made from these alloys is recommended for large cranks and propeller-shaft forgings, for large guns, rifle barrels, and for wiring and for boiler plates. The molybdenum increases the elongation of steel very considerably, and for wire drawing such an increase at a comparatively small cost is important.

VANADIUM STEEL.

On account of the extremely high price and scarcity of vanadium ores, the metal has thus far been employed very little in the manufacture of ferrovanadium for use in the production of vanadium steel. It is claimed by many that the beneficial properties imparted to steel by vanadium exceed those of any of the other steel hardening metals. These are exaggerated statements, but it may be found that smaller quantities of vanadium will give in some cases the same results that are obtained by comparatively large quantities of the other metals. One property claimed for vanadium steel is that it acquires its maximum of hardness not by sudden cooling, but by annealing at a temperature of from 1,300 to 1,470 deg. F. This property would be particularly advantageous for high-speed tool steel and for points of projectiles. There is, however, at the present time little or no vanadium steel on the market.

TITANIUM.

The actual commercial value of titanium as a steel-hardening metal has not been thoroughly demonstrated. Experiments have shown that from 0.5 to 3 per cent of titanium increases the transverse strength and the tensile strength of steel to a very remarkable degree. Until the development of the electric furnace it was practically impossible to produce either titanium or an alloy of iron and titanium, but since the introduction of this furnace ferrotitanium can be produced directly from the ores. It is to the manufacture of a special cast iron that ferrotitanium seems to be especially adapted. The titanium in the iron gives greater density to the metal, greatly increases its transverse strength, and gives a harder chill or wearing quality to a wheel made from such an iron. For the manufacture of car wheels it would seem that the titanium iron would be especially useful.

DISTANCE CONTROL BY ELECTRIC WAVES.

WIRELESS telegraphy embodies the simplest application of induction effects due to electric sparks, resulting in the repeated attraction of an electromagnetic contact, the intervals being so controlled as to indicate the various signals to be transmitted. Now Prof. E. D. Branly has endeavored, by the aid of electric waves, to attain at the receiving station several other effects without the interference of an operator at that station.

An experimental apparatus, which was recently presented by the inventor to the French Academy of Sciences, operates with perfect regularity in a laboratory, so that an extension of its range to that of practical wireless telegraphy would seem to be quite feasible. The following three effects have been more especially studied: Starting an electric motor; causing incandescent lamps to glow; causing an explosion.

All these effects can be produced or discontinued in any desired order, one after the other. It should, however, distinctly be understood that they have been chosen quite arbitrarily, and that any other mechanical action, or in fact a series of actions depending on one another (constituting, for instance, the working of a complicated machine) could be brought about or discontinued quite as well.

The distributor of the action in question consists of an insulated shaft on which are mounted some metal disks, rubbing against brushes and springs to allow the electric current to pass. The shaft is driven by a clockwork, and each disk is obviously an interrupter that corresponds with some special phenomenon it is able to produce or to discontinue, and which is determined by its shape.

Choosing as an example a disk to be employed in the lighting of incandescent lamps, the edge of this disk strikes constantly against a brush. On the disk's circumference there is a sector of about 90 deg., having a radius somewhat greater than the remaining cir-