sulphate, and copper, operates at first only upon the copper, and finally in the reduction of the iron salts; so that, with the same number of coulombs, no more than half the copper is deposited. Consequently, with anodes in which the copper and iron are of equal weight, we may calculate upon a rendering of 75% of the electric energy employed. If the copper increases, the rendering will be greater, and, on the contrary, less if it diminishes. It cannot, however, get below the 50% that is obtained when there is no longer any copper in the anodes.

What is essentially striking in all these experiments is that it has never been necessary to employ potentials greater than one volt; on the contrary, the tensions have always remained below that figure.

Although we have accurately determined the limit electromotive forces of each couple, we do not think it necessary to give a *resumé* thereof. Since the metallic sulphides obtained through fusion not being definite chemical compounds, there result numerous variations for each measurement; and, moreover, such researches, though interesting to science, are not of much help to the industry.

In conclusion, we shall set forth the most important facts that the manufacturer may avail himself of in applying the process. They are as follows:

1. Metallic sulphides obtained through fusion are compounds that conduct electricity very well. From numerous experiments performed in our laboratory with Thomson's double bridge, as modified by Kirchhoff and Hausman, it results that their conductivity comes much nearer that of metals than of that of the electrolytes (except copper sulphide, Cu_2S , which has a very great resistance).

2. The decomposition of the metallic sulphides, employed as anodes, requires an expenditure of work much less than that required by the sulphate.

3. By employing anodes composed of iron-copper-sulphur, such as result from a first ordinary fusion, we may always remove the copper with an electric rendering which is comprised between 50 per cent. in cases where there is no longer any copper in the anodes and 100 per cent. when, on the contrary, there is no more iron.

4. With the use of metallic sulphides for anodes, we may recover in a metalloid state all the sulphur contained in the mattes.

5. Finally, the extraction of copper based upon this process offers an exceptional simplicity as compared with the different metallurgical treatments in use. In fact, we know that the metallurgy of copper requires at least three fusions: that of concentration, that of the production of crude copper, and that of refining. Besides, often-renewed roasting is necessary in order to remove the sulphur completely. In the electrolytic process there is only the production of the matte and its electrolytes in order to at once obtain refined copper.

All these results, which are confirmed by experiment, gave us the hope that we might be able to successfully try this process in a practical manner. Without disguising the numerous difficulties that we had to meet with to carry out these laboratory experiments upon a large scale, and the importance of which will be justly appreciated only by those who are occupying themselves seriously with this question, the full confidence that we had in the correctness of the principles upon which the process was based completely justified the employment of the large capital that has been embarked in it.

Happily, our studies, which were always pursued with constant perseverance, have been crowned with entire success, and we shall now pass in review the different apparatus employed, and the process followed, at the Sestri-Levante Metallurgic Establishment, which is arranged in such a way as to produce two tons of electrolytic copper per day.—G. Badia, in *La Lumière Electrique*.

THE PRESERVATION OF IRON BY ONE OF ITS OWN OXIDES.*

By Mr. B. H. THWAITE, Assoc. M.I.C.E.

WHEN iron is exposed to contact with ordinary moist atmospheric air, it unites with the oxygen of the latter, to form two varieties of oxide of iron; in the first instance, the ferrous oxide (FeO), which becomes rapidly converted into another, or the second variety, the ferric oxide (Fe_2O_3). If a piece of iron is exposed to oxidizable influences sufficiently long, its entire substance will become oxidized; for as soon as the superficial film of oxide on the surface of the iron becomes converted into the second variety, or ferric oxide, part of its oxygen is transmitted to the metallic surface beneath it to form ferrous oxide, and this latter also becomes in its turn converted into ferric oxide, and again transfers its oxygen to the still remaining metallic iron; and this process goes on continuously until the whole of the iron becomes oxidized. Hence, if iron is not protected from this oxidation, corrosion, or action of decay, its strength becomes in time seriously impaired. As will be seen from the formula† (arranged by the author, and based on a series of experiments on the action of the oxidation of iron, in order to ascertain the metallic life of iron with a tolerable degree of exactitude), it appears that a bar of wrought iron, 4 inches $\times$ 1 inch, subjected to the corrosive atmospheric influences of a manufacturing city, would be entirely corroded away in a little over a single century. Fortunately, however, besides the two combinations of iron with oxygen already mentioned, there is a third, or the magnetic oxide, Fe_3O_4 , a most stable oxide, and, as in the examples of the oxides of zinc and copper, once properly formed of a certain thickness, it arrests further oxidation of the iron. It is found in a natural state on the shores of New Zealand, in the form of black titaniferous sand, and although the sea water is constantly washing over it, its stability is apparently unaffected. Lavoisier is credited with the discovery of the artificial formation and stable properties of the magnetic oxide, and the late Mr. Robert Mallet, M.I.C.E., discovered it during one of his experiments. Berthier noticed it when iron was subjected to highly-heated air, and Thirault is said to have produced the magnetic oxide in 1860, in a very peculiar manner. A modification of Thirault's process is now adopted by gun-

makers, who, by means of processes, although long and tedious, succeed in obtaining a most beautiful coating of oxide.

The Russian sheet iron is covered with a thin and rather pliable film of this magnetic oxide, but whether this coating of oxide was originally applied by accident or intention, it is impossible to say. An interesting paper, by Dr. Percy, F.R.S., Hon. M.I.C.E., "On the Protection from Atmospheric Action which is imparted to Metals by a Coating of certain of their Iron Oxides respectively," was read at the meeting of the Iron and Steel Institute, in Newcastle-upon-Tyne, in September, 1877.* In Russia and in the United States common use is made of this sheet iron for covering locomotive boilers and steam cylinders, as well as for roofing purposes. Some years ago Professor Barff, F.C.S., while engaged in experiments in peat charring, noticed the formation of this peculiar oxide, in a pipe conveying highly-heated steam, and observed its preservative action on the iron. He at once commenced a series of experiments and investigations which resulted in the elaboration of a process for producing magnetic oxide, for the purpose of preserving the surfaces of iron. Professor Barff's process is a practical adaptation of Lavoisier's principle. In his specification, Professor Barff describes the process as follows: "In carrying out my invention, I place the objects composed of iron or steel in a muffle or chamber, so constructed as that it may be in part wholly closed, and so that the contents of the interior of such muffle or chamber may be raised, by means of external heat, to an elevated temperature, and when the objects or articles have acquired a temperature sufficiently elevated to cause the decomposition of steam or aqueous vapor when brought into contact therewith, I inject the same, and continue the action of the steam, or the aqueous vapor, until the desired protective film or coating of oxide has been produced." On hearing of Professor Barff's process, it occurred to Mr. George Bower that highly-heated air might possibly be used with success for obtaining a coating of magnetic oxide. Mr. Bower made a series of experiments with air as an agent, and a sample of iron that was subjected to one of Messrs. Cochrane's hot-blast stoves was found to have a most decided and a herent coating of magnetic oxide. The first furnace devised for carrying out the air process consisted of an externally-heated chamber, in which the iron articles to be treated were placed. When the iron articles had attained the temperature of oxidation, a few cubic feet of ordinary atmospheric air were blown into the chamber, which was closed, and the iron then entered into combination with the oxygen of the air, a thin film of magnetic oxide being formed on the metal. Fresh air was admitted from time to time, to replenish the oxygen appropriated by the iron, until the requisite thickness of oxide was attained.

The difficulty and expense of the application of external heat were so great that it occurred to Mr. Bower's son, who was conducting experiments, that, if internal application of heat could be substituted, and the coating of magnetic oxide produced simultaneously with the action of heating, by a series of oxidizing and deoxidizing operations, the process would be much simplified, be more effective, and far less costly. Elaborate experiments were conducted with this aim, and the results far exceeded anticipation. On the basis somewhat of a special furnace, devised and arranged by the author, Mr. Anthony S. Bower developed a furnace for carrying out this process. In this furnace the combustible gases are generated in three producers (in the furnaces first designed, an ordinary single Siemens producer, with inclined plates, was used, but owing to the irregular supply and quality of the gas, it was decided to adopt three). By this arrangement a regular plenum of gas can always be obtained; moreover, the producers are admirably adapted to the form of the furnace. They not only act as buttresses to resist the thrust of the furnace arch, but they prevent wasteful radiation. Coals are charged through specially devised plug hoppers. The plugs, in being withdrawn, permit the coals to fall into the producers with a minimum escape of gas. The Siemens balanced coal-charging boxes were tried, but they were abandoned in favor of the form described. The gases evolved by the distillation of the coal pass over partition walls, descending by a downcast, in which is fixed a regulating valve. The gas then passes along a horizontal flue to the mouth of the combustion chamber, when it meets the current of heated air ascending from the recuperators. Combustion here ensues, perfect mixing and oxidation of the gases being attained by a series of intercepting checker walls; the products of combustion then pass into a side flue, where they ascend into the furnace or muffle. The products of combustion descend from the muffle into a side flue, passing from thence into the recuperator, where, by going round air tubes of fireclay, they transmit their heat to the air flowing to support combustion. The products of combustion then escape into the chimney flue. The air passes into the recuperators by means of a regulating valve, and after flowing through the whole length of the tubes in the recuperator chamber twice, it ascends into a port, where it meets the combustible gases coming from the producers.

The cast-iron articles to be treated are placed in the chamber or muffle, and gradually heated by combustion of producer-gas within the chamber up to the temperature of oxidation, say 1,600° Fahr. The oxidizing process is then commenced, first by submitting the iron to an oxidizing flame, that is to say, by allowing highly-heated air in excess of that necessary for combustion to enter the furnace. The oxygen of this air in excess enters into a double combination with the iron. On the immediate surface of the iron a film or coating of the magnetic oxide (Fe_3O_4) is formed, and over this a film of sesquioxide (Fe_2O_3). This oxidizing operation generally occupies about twenty minutes. The air-valve is then entirely closed, and the combustible gases from the producers (carbon monoxide, etc.) are allowed to enter unconsumed into the muffle. By this operation, a deoxidizing one, the sesquioxide is converted into the magnetic oxide; this deoxidizing operation generally occupies from fifteen to twenty-five minutes, the duration entirely depending upon the quality of the coal-gas. The richer it is in carbon, the less the time required to effect the deoxidizing operation. The air-valve is now opened, and another double combination of oxygen and iron effected, which, by another deoxidizing operation, is reduced to one combination of

Fe_3O_4 , the magnetic oxide. It will be understood that by repeating the alternate operations of oxidation and deoxidation sufficiently often, the entire metal could be oxidized. The duration of the process depends upon the size, number, and intended use of the articles. For instance, only six double-oxidizing and deoxidizing periods are necessary for articles intended for internal or indoor use. For articles intended to be subjected to external atmospheric influences, from ten to twelve double periods of oxidation and deoxidation are necessary. Owing to the great sensitiveness of wrought malleable iron and steel to oxidizable influences the Bower process produces the coating of oxide in these varieties too rapidly, and it is not sufficiently uniform or adherent; and the Barff process has been found by experience to be more satisfactory for producing the magnetic oxide coating on the surfaces of malleable wrought iron and steel.

However, the two inventors combined their respective processes, and a furnace having the economic features of the Bower furnace was designed to effect the Barff process. In the preliminary experiments great difficulty was found in obtaining a satisfactory and durable form of steam superheater. Circular coils of lap-welded steam-pipes were first tried, but, although effective as superheaters, their cost and liability to stoppage, the necessity of frequent renewal, and the rapid oxidation of the wrought iron, were grave objections, and cast iron was used in the form of a rectangular casing of the whole length of the furnace, and filled with small cast-iron balls. In order to prevent the oxidation of the casing, its outer sides were grooved, to retain a refractory lining of a mixture of silicate of soda and fireclay; but this lining soon commenced to crack and flake off on continuous exposure to the flame. Further, the oxidation and expansion of the cast-iron balls produced fracture in the outer casing; in other respects this form of superheater gave highly satisfactory results.

The form of superheater now adopted consists of a cast-iron casing, rectangular in section, having a longitudinal division dividing the casing into two parts. The steam entering the lower division is compelled to traverse the whole length of the superheater twice before it can escape; to increase the heating surface, the cast-iron casing is filled up with broken pieces of fireclay of irregular size; the sides of the cast-iron casing are protected from actual contact with the flame by means of fireclay tiles. The superheater can be renewed without disturbing any part of the structure or cooling down the furnace, a great desideratum, as the latter operation is very detrimental to the condition of the furnace. The superheater is connected to the muffle by means of an expansion coil, which permits the superheater to expand and contract. It further serves as a pyrometer, as by the relative visible temperature of the coil, which can be visually examined by removing a portion of the loose coal ashes which cover it, the temperature of the steam entering the muffle can be ascertained.

A great difficulty was at first experienced in arranging a satisfactory rolling carriage, for carrying into and out of the muffle the articles to be oxidized; but the difficulty has been solved by an arrangement consisting of a cast or wrought iron table having equally distributed perforations over its entire surface, and having horizontal cast or wrought iron webs or ribs on its underside, which keep the differential rolling arrangements in position. This latter consists of a series of double rollers, their peripheries running in the channels formed on the under side of the table, and upon the false cast-iron base-plate forming the muffle floors. The rollers are held together by wrought-iron bars. By this arrangement, although there is no part of the rolling apparatus actually bolted, the carriage runs as freely and firmly at a temperature of bright red heat as when cold, and each part can easily be removed and renewed.

A point of importance to insure the success of the process is the arrangement of the articles on the table before treatment. If placed indiscriminately and carelessly upon each other, they may become distorted during the process. All articles of any great length should be laid perfectly level, and be evenly supported, with sufficient space to allow for expansion. This is easily accomplished by the form of cradle or frame used. This consists of a framework of wrought-iron bars. Loose T-irons, bent at the ends, so as to hang over the horizontal bars of the frame, are fixed in any position suitable for supporting uniformly and level the articles to be treated. The treating table is drawn in and out of the muffle by means of a crab-winch. When ornamental or other castings of great delicacy of form are treated, a sheet-iron cooling cover is lowered to receive the table as it is withdrawn from the muffle. This allows the castings, etc., to be very slowly cooled; but generally this cooling cover is not required, as the accumulated heat of the carriage and framereleases the air and prevents the castings from becoming cooled too rapidly.

After the articles to be treated are properly arranged on the table, the chain from the winch is attached to a portable handle, which is dropped into holes in the table. The muffle doors are then lifted, and the table is slowly and carefully drawn into the muffle. The doors are next lowered, and with a trowel the attendant lutes their edges with a mixture of loam and sand. Just before the articles are drawn into the muffle the steam is gradually turned through the superheater into the muffle. A pressure varying between one atmosphere and two atmospheres is all that is necessary, as great pressure only forces the steam too rapidly through the superheater. What is necessary, before the articles are placed in the muffle, is that a plenum of steam should be established, in order to prevent the influx of air into the muffle; the heat of combustion is then turned fully over it, and by withdrawing the damper is afterward directed on to the superheater, where it is compelled to pass under and over the latter by baffler walls. These also support the floor of the muffle, and act as accumulators of heat. After passing around the superheater, the products of combustion may be directed into a steam-generator. In the works of the Bower-Barff Rustless Iron Company at Southwark, it is intended that the waste heat shall, on its way to the chimney, be directed through the tubes of one of Cochrane's patent vertical multitubular boilers—a form of steam-generator very suitable for this purpose.

After the temperature of oxidation is attained in the

* From the selected papers of the *Proceedings of the Institution of Civil Engineers*.

† Molesworth's *Pocket-Book of Engineering Formulae*, twenty-first edition, p. 33.

* *Journal of the Iron and Steel Institute*, 1877, pp. 456-480.

muffle, the flow of combustion is almost entirely directed immediately on to the superheater, by withdrawing the damper; only as much heat being allowed to pass round the muffle as will maintain the temperature of oxidation; the temperature of the muffle can be ascertained either by using a pyrometer, or visually, by withdrawing one of the movable sight-plugs provided in the doors. If the articles are covered with rust before they are treated, the rust must be reduced, immediately the temperature of oxidation is attained, by first shutting off the steam from the muffle, and turning into it instead carbon monoxide gas from the producers, by means of a valve and its connections. During this process a good pressure of CO gas must be maintained, otherwise there is a danger of the ingress of air into the muffle. After the process of deoxidation, which varies in time according to the extent of the rustiness of the article, the steam must be turned on carefully.

Another deoxidizing process is occasionally used, with very good results. The method is as follows: Oil is poured into a funnel, having a siphon bend, from which it passes into the muffle by a $\frac{1}{2}$ inch gas pipe. In its passage through the latter the oil becomes decomposed and volatilized, and the hydrocarbon vapors, being prevented from escaping by the liquid seal of the oil siphon bend, are driven into the muffle, where they effectually convert the red rust Fe_2O_3 into the magnetic oxide Fe_3O_4 . It is important, in order to prevent the possibility of the influx of air into the muffle, that a continuous and uniform pressure of steam should be maintained. The least admission of air will produce an imperfect and unstable coating of magnetic oxide. Generally, when air obtains ingress into the muffle, the articles are found to be covered with a film of oxide of a brilliant red color and having a lustrous appearance. When this occurs, the furnace should be at once examined, as it is a clear proof that air gets into the muffle somewhere.

Occasionally there may be a leakage, and air may enter in such small quantities as not to exhibit the phenomenon described, and such has been the case with one of the furnaces at St. Neots. The magnetic oxide coating, although apparently perfect, was, after a few times' exposure to oxidizing influences, found to exhibit incipient signs of red oxidation. On examination the muffle was found to have a fractured plate. In an externally heated muffle, like that of the Barff furnace, it is possible to regulate the temperature to a nicety, a feature of great importance when intricate and delicate articles of steel or wrought iron require oxidizing; but for heavy cast-iron articles external heating is very disadvantageous, both from the question of economy in the use of fuel and in the time required to heat the articles up to the temperature of oxidation. Hence the advantage for cast iron of the internal and direct heating features possessed by the Bower process. Another great advantage of the latter process is that the progress of oxidation can be readily and almost closely examined during one of the oxidizing operations. Through one of the sight-plugs in the muffle-door a lighted gas-rod is inserted, and by looking through one of the other adjacent sight-plugs, the exact character and progress of the oxidation can be clearly seen; hence the process is exactly reliable, and there need be no sense of uncertainty as to results.

By the Bower process a most effective coating of magnetic oxide can be obtained in from three to eight hours, according to the thickness, character, and size of the articles to be operated upon. In this process the rustier the articles are, the more effective and speedy is the process of oxidation. Old cast-iron water and gas pipes, that were so covered with rust as to be commercially valueless, have been converted into a condition more durable and valuable than they were when first withdrawn from the moulder's sand. The magnetic oxide coating produced by the Bower furnace, on the surface of the roughest castings, is smooth to the touch, and has almost the finished appearance of enamel. The smoothness of the surface is, however, more apparent than real, as by microscopical examination the surface presents a granular appearance. If occasionally the articles are slightly warped, they can, by a judicious re-heating, accompanied by the application of pressure, produced by weights, etc., be brought back to their original shape.

A French chemist, Mr. Dode, discovered, some years ago, a singularly cheap and beautiful process for depositing from their salts the noble metals upon the surface of a special description of enamel, which was fused upon the surface of iron and steel articles; but it was discovered that corrosion unfortunately set up under the coating of enamel, and eventually threw it off. It was decided to try Mr. Dode's process upon the magnetic oxide coating as produced by the Bower process, and the experiments proved a decided success. The Societe Francaise d'Inoxidation et de Platinage, though proprietors of Mr. Dode's patent, also purchased the Continental patents of Mr. Bower and eventually those of Mr. Barff as well. By a special arrangement of the furnaces, Mr. Roque, the engineer of the Societe Francaise, is able to treat articles of a very considerable length.

The color of the magnetic oxide coating as it emerges from the furnace is a light tint of French gray, which can be made to have a silvery, lustrous appearance by merely filling the muffle with the vapors of volatilized liquid hydrocarbon, produced from oil poured into a special siphon formed as already described. The color of French gray will be retained by the magnetic oxide as long as it is free from contact with liquid grease, oil, or other hydrocarbons. The least touch of any of these instantly converts the light French gray color into one of a bluish-black appearance, which no energy of washing or rubbing will remove. But of course the grease or oil is volatilized on exposure to heat, leaving the oxide with its original color. All articles that are likely to be handled should be oiled. Mineral oil is the most suitable; and as the coating of magnetic oxide rapidly absorbs the oil, the least application is sufficient; and after the superfluous oil has been thoroughly rubbed off, the oxide presents a dark and polished appearance, which to some people is preferable to the delicate natural color of the oxide. A very pretty effect may be obtained, upon ornamental castings, by oiling the minor or subordinate parts of the ornament, leaving the prominent or main parts untouched. In the preliminary experiments with the magnetic oxide

it was noticed that if any foreign metal was rubbed upon its surface, part of the latter was deposited or left on the former, a property not possessed, as far as the author knows, by any other oxide; this remarkable discovery led Mr. Bower to make a series of experiments with various descriptions of metallic brushes with wires of all the noble metals, as well as of various alloys; in all cases the results were the same, and oxidized castings can be gilded, platinized, or bronzed, etc., most charmingly, cheaply, and quickly by merely rubbing over the surface of the magnetic oxide coating with metallic brushes with bristles of any description of metallic wire other than iron. In order to permanently fix the gilt, the gilded castings are exposed to very moderate temperature—say 600° Fahr.—for about thirty minutes.

As already mentioned, the Societe Francaise d'Inoxidation et de Platinage utilizes the magnetic coating as a base for receiving their special enamel. Upon this enamel, or even direct upon the magnetic oxide coating, gold, silver, platinum, etc., can be permanently deposited by mixing the chlorides of these metals with certain essential oils, and then placing the iron articles, washed with the metallic chlorides, in the furnace for a short time. The novel feature of both the attrition and Mr. Dode's principle of gilding, platinizing, etc., is that the same iron article can be ornamented with various metals, in conjunction, if desired, with other coatings, such as variously colored enamels. When the oxidized castings require to be enameled, no costly preliminary process of annealing is necessary, and the enamel can be deposited direct upon the coating of magnetic oxide. The strength of constructional ironwork is practically unaltered by the Bower-Barff process.

The following may be taken as a fairly accurate list of the thicknesses of the magnetic oxide coatings required for various descriptions of iron:

	Inch.
Light sheet iron, a thickness of	0.0035
Light wrought iron, a thickness of	0.0104
Heavy wrought iron (such as tubes), a thickness of	0.0188
Light cast iron (such as tubes), a thickness of	0.0183
Heavy cast iron (such as tubes), a thickness of	0.0200

As the magnetic oxide is not very pliable, it is not suited for articles which have to be bent after their treatment, and if struck very violently with another hard metallic body, it is liable to chip off at the point of contact; but when the process is properly accomplished, the oxide coating will withstand all ordinary concussions. If a piece of the oxide coating is, however, removed, the corrosion which may set up in the denuded portion will be strictly local, and will not burrow under the coating remaining intact. If the magnetic oxide is perfectly formed, it will resist all ordinary corrosive influences; but it is affected by contact with strong corrosive acids, although a piece of oxidized cast iron has been found to resist for a considerable period the action of dilute acids, such as urine; but the author would not advise its adoption for apparatus used in the chemical industries, except in the laboratory, where it has been utilized with success for preserving iron tripods, Florence flask-holders etc. Fe_3O_4 represents the chemical equivalents forming magnetic oxide, hence the relative equivalent weights will be as follows:

$$\begin{aligned} 3(56) &= 168, \text{ or } 72.41 \text{ per cent. Fe.} \\ 4(16) &= 64, \text{ or } 27.59 \text{ per cent. O.} \end{aligned}$$

It is magnetic, as its name implies, and has a specific gravity of from 4.98 to 5.20. To test the character of the magnetic oxide coating, the oxidized articles are placed upon a damp soil, say for two hours, and are then allowed to become dry in the open air. These alternate processes of exposing the oxidized articles to wet and dry periods are continued for several days, and if the coating is imperfect, a few days' exposure to the test described will bring its imperfections to light. If the oxide coating resists satisfactorily the test experiment for a period of five or six days, it is perfect and durable. One of the greatest advantages possessed by the Bower-Barff process is the completeness with which the oxidation is effected upon every part, however intricate it may be, of the metallic surface of the articles submitted to it; hence its applicability to hollow cylinders, pipes, etc., of intricate shape. Owing to the increased size of the articles submitted to the process by the addition of solid oxygen, it is necessary that all parts which have to be fitted together, such as screws, bolts, etc., should be slightly run down or otherwise decreased in size to allow for this addition. The magnetic oxide coating, giving as it does a finished appearance and smoothness to the iron, the latter can be painted, if desired, far more easily than if it was unoxidized, and the painted surface will be far more durable. Ordinary oil-paint, when applied to unoxidized iron, has only a comparatively short life, arising from the fact that the moisture of the condensed aqueous vapor on its surface eventually permeates through the paint, setting up corrosive action, which ultimately throws it off; hence the importance of having iron articles oxidized or Bower-Barffed, even if it is desired that they should be painted as well.

It will no doubt be obvious that the cost of oxidizing by the Bower or Barff process—or, to use a more abbreviated expression, the cost of Bower-Barffing—varies considerably; for example, one thousand small articles may be treated at the same time, and in the same cubical space, that might be occupied by a single large article; but when the latter is hollow, and when possible, the hollow space may be filled up with smaller articles. Mr. Flamache, engineer for the Belgian state railways, who was sent over by the Belgian Works Department to report on the process, found the cost, exclusive of royalty, to be as follows: 7½ francs per 1,000 kilogrammes by weight, or $\frac{3}{4}$ of a centime per kilogramme; and superficially, $\frac{3}{8}$ of a centime per decimeter cube. In the Bower furnace of the Societe Francaise at Grenelle, the weight of objects treated in twenty-four hours varies from 47 to 85 cwt., with an expenditure of fuel of from 10 to 12 cwt. of good slack coal. In the Barff furnace, of the same form, the weight of objects that can be treated in twenty-four hours varies from 47 to 106 cwt., with an expenditure of fuel of from 15½ to 17½ cwt. For a Barff furnace having a muffle capacity equal to 124 cubic feet, the quantity of water evaporated per hour to supply the muffle

with superheated steam is equal to from eight to ten gallons. One attendant is required for every two furnaces in ordinary working; but auxiliary labor is required when loading or unloading.

The following is a list, necessarily limited, of articles especially adapted for receiving the coating of magnetic oxide:

Cast Iron.—Architectural ironwork; horticultural ironwork; sanitary appliances; engineering ironwork, such as water-mains, gas-mains, roof and bridge castings, etc.

Wrought and Sheet Iron; Untempered Steel.—Water, gas, and pneumatic tubes; cramps, roofing tiles, and generally all ironwork which will not be liable to rough usage, and not require bending or riveting after treatment.

It will probably be seen that the Bower-Barff process is applicable to those articles to which galvanizing is more or less inapplicable; and the former process therefore serves as a useful auxiliary to that well-known and excellent process of preserving iron by means of a coating of zinc. For the Bower furnaces in New York, in place of bituminous coal, anthracite is used in the producers, in conjunction with gas from petroleum oil. The latter is allowed to trickle slowly through the coal-charging hopper of the central producer, where, falling upon the anthracite incandescent fuel, it becomes volatilized, and produces a very powerful reducing or deoxidizing gas. In order to prevent the oil from igniting and firing back, it is led by a pipe from a considerable distance. In the New York Bower furnaces, equal periods of both oxidation and deoxidation, of a duration of fifteen minutes each, are found to give very satisfactory results. In the same Bower furnaces Mr. A. S. Bower has been successful in carrying out the Barff process for heavy wrought-iron articles by the following method: After the wrought iron articles have been heated by direct combustion inside the muffle apparatus to the temperature of oxidation, the gas and air are shut off from the muffle; the chimney damper is closed, and steam is turned into the recuperator tubes, and in passing through them toward the muffle becomes highly heated. The steam is kept on continually until the temperature of the articles begins sensibly to decrease, when it is shut off, and the gas and air are turned on (in such relative proportions as not to affect the character of the oxide coating), until the proper temperature is again regained; and the same operations of shutting off gas and air, etc., and turning on steam, are repeated as often as required to effect a proper thickness of the oxide coating.

THE SPECTROSCOPIC EXAMINATION OF THE VAPORS EVOLVED ON HEATING IRON, ETC., AT ATMOSPHERIC PRESSURE.

By JOHN PARRY, Ebbw Vale.

METALLURGISTS favored with opportunities of observing the behavior of metals while being heated or fused are of opinion that the fumes usually seen are due to the volatilization of the metal itself, or of some more volatile constituent.

In casting alloys of the more fusible metals, this dissociation or volatilization is an accepted fact, and is usually considered when adjusting the proportions of the constituents. Alloys of the more infusible metals, such as iron, manganese, nickel, cobalt, etc., have not been studied; but those who have observed the behavior of the crude iron and steel while being fused, or otherwise manipulated at high temperatures, have noted that, in addition to the well-known evolution of gas, fumes are given off, which has led to the inference that, as before stated, some more volatile constituent is being evolved; and Professor Ledebur asserts that as iron is being volatilized the chemical composition of the metal may be changed, presumably within certain narrow limits. It may be that crude iron is slowly dissociated, and certainly at the high temperature of the Bessemer process iron is volatilized, and may be seen far above the mouth of the converter, forming a red cloud, quite unlike ordinary smoke or vapor.

The spectroscopic examination of the flames issuing from blast and other furnaces shows only continuous spectra, with but few lines, very similar to the spectrum of the ordinary Bunsen flame, with the exception of the Bessemer flame, which gives the carbon spectrum, together with (according to some observers) that of manganese.

I have, however, found that many of the metals are volatilized at a comparatively low temperature, but give only continuous spectra when examined in the flame. The vapor requires the intense heat of the electric spark to be passed through it to insure complete dissociation, and consequent production of the usual line spectra. (A list of metals tested is attached hereto.)

Spiegeleisen fused in a crucible evolved a fume in which I detected zinc, copper, manganese, calcium, and, with less certainty, magnesium.

Bessemer pig-iron, similarly treated, gave copper, manganese, calcium, either lead or arsenic, as well as gas burning with a flame resembling that of carbonic acid.

Bessemer pig-iron burnt in a stream of oxygen at a dull red heat gave copper, manganese, etc., as before, but more intensely; also a great number of lines which appear to be derived from iron. This spectrum requires careful study, and, when developed, may throw some light on the reactions occurring during the Bessemer blow.

Spanish iron ore reduced in a crucible with charcoal, at a heat sufficient to form a button of fused metal, evolved zinc, copper, and manganese.

It is therefore probable that matter may be evolved during the ordinary heating processes in the manufacture of iron and steel, as previously explained, but giving no visible indications of the fact, in consequence of the heat being sufficient only to volatilize without effecting dissociation.

With my present limited experience, I am of opinion that the actual quantity of matter evolved from iron, steel, etc., is very small, and not at all likely to affect the quality of the coarser kinds of iron and steel, although it may be otherwise when a material of good quality and great purity is required.

The germ of the foregoing is to be found in the recent work of spectroscopists, more especially of Mr. Lockyer, who, in his "Studies in Spectrum Analysis"