

Iron Manufacture by Electrolysis*

Properties and Industrial Applications of the Product

By L. Guillet

THE industrial manufacture of iron by electrolysis is a problem which has engaged attention for many years, but it is only within the last year that it has entered the practical stage. In principle, the method consists in the use of a revolving cathode and a neutral solution of iron salts, maintained in the neutral state by the circulation of the liquid over the surface of the iron. The bath also receives periodic additions of a depolarizing medium, such as oxide of iron, the object of which is to eliminate, at least in part, the hydrogen deposits on the cathode, which injuriously affect the material if present in too large a quantity. By these means it is

tle. In fact, two effects are produced in the process of manufacture. The metal is interstrained and has absorbed gases, particularly hydrogen. On heating in vacuum between 800 and 1,100 deg. Cent. for four hours, and then raising it to the neighborhood of 1,400 deg. Cent. for a further two hours, Sir Robert Hadfield found that 34 grammes of the iron had a volume of 4.3 cubic centimeters and yielded 28.8 cubic centimeters of gas of the following composition:

	By Volume. Per Cent.	By Weight. Per Cent.
Hydrogen	18.8	65.3
Carbon monoxide	7.4	25.7
Carbon dioxide	0.2	0.7
Nitrogen	2.2	7.6
Oxygen

The presence of carbon monoxide is somewhat noteworthy. On its removal from the electrolyte, the iron is very brittle, and has a Brinell hardness of 193, using a ball of 10 millimeters diameter under a load of 3,000 kilogrammes. The micrographic examination reveals an entirely characteristic structure, consisting of innumerable fine needles, very much resembling martensite.

After annealing for two hours in magnesia at 900 degrees, the iron shows a Brinell hardness of 90. The micrographic structure is perfectly normal. The tensile test gives a breaking strength of 30.9 to 32.8 kilogrammes per square millimeter, and an elongation of 40.2 to 42.1 per cent in the direction of the axis of the tube. Further, the annealed tubes, when subjected to compression tests, can undergo deformation to an extraordinary degree without a sign of any fracture, as shown in one of the illustrations.

INDUSTRIAL APPLICATIONS.

The industrial applications of electrolytic iron fall into three principal categories: (1) the direct manufacture of tubes; (2) the direct manufacture of sheets; (3) the preparation of pure iron as a raw material intended for fusion. There are various other uses of less importance, such as the preparation of rods of very pure iron for autogenous welding.

Tubes.—The manufacture of tubes is being proceeded with on an industrial scale by the Bouchayer & Viallet Company, whose installation is capable of turning out 100 tubes per day. The current practice of this company is to manufacture tubes 4 inches long, 100 to 200 millimeters in diameter, with a thickness of 0.1 to 6 millimeters. Some of these are shown in one of the illustrations. As is well known, all present methods of manufacturing tubes present certain insurmountable difficulties when it is desired to obtain regular thicknesses of less than 6 millimeters. As a general rule, in the products obtained the thickness of the wall is far from constant. With the electrolytic process it is possible to obtain the most satisfactory regularity whatever the thickness, diameter, and length of tube.

The tubes will withstand considerable pressures. Thus, a tube of 100 millimeters diameter and 0.75 millimeter thickness, subjected to 1,200 pounds per square inch, underwent a permanent deformation of a regular character, as if squeezed in a press. Another specimen of the same tube was exposed for two and a half months to a temperature of 120 degrees in a boiler. It was then tested to 1,200 pounds per square inch, but no trace of fracture was perceptible.

Sheets.—The manufacture of sheets is under investigation, but no doubt the researches in the industrial laboratory will lead to a method by which they can be produced commercially. The importance of being able to obtain sheets direct without rolling will be appreciated. The iron is of first-class quality, capable of undergoing very considerable deformations in the cold. Tests on tubes and plates have been made in the draw bench, and it is surprising with what facility the metal can be worked. The material is therefore highly suitable for purposes of stamping, both in the form of plain annealed plates (black plates) or of tinned plate. Finally, on account of their purity, these sheets are especially adaptable for use in the construction of electric machinery. Dr. Max Breslauer of Berlin has demonstrated the important aspect of this question, both from the point of view of magnetic properties and of regularity of thickness and compressive strength. The efficiency of alternating motors and transformers, and also of direct current motors, is increased by using this material in their construction. He concludes that the use of electrolytic iron constitutes a real progress, both as regards hysteresis and permeability. In transformers the saving in weight of material is 33 to 40 per cent. The capacity of alternating motors can be increased by 50 per cent, running

at the same temperature, and occupying the same space. In direct current machines, 16 per cent of the iron can be saved.

As a Raw Material for Fusion.—Without doubt electrolytic iron will be able to compete successfully with Swedish iron. The quality is much more regular, and the crude metal, being very brittle, can easily be broken into pieces of any required size, however small, and, at the same time, it can be supplied in suitable thicknesses. The cementation of such products would be more regular than those ordinarily used. Tests made at various steel works have shown that tools and special steels manufactured from this material give results at least equal to those obtained with Swedish iron. The cost price is the only remaining consideration.

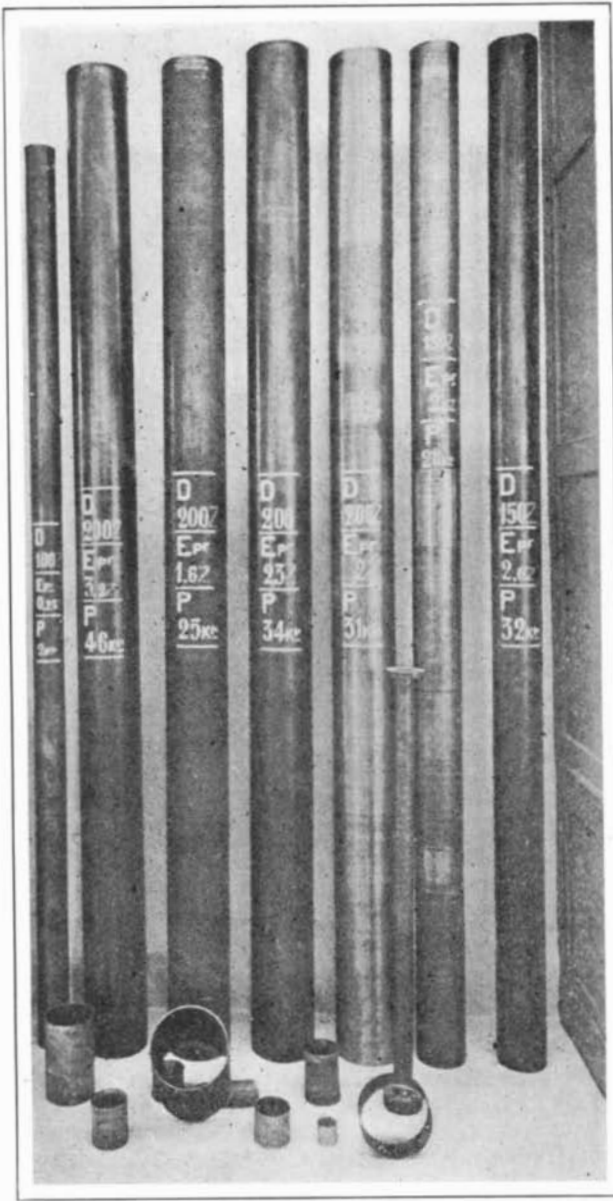
COST OF MANUFACTURE.

The principal factors which make up the cost price are the electric energy and the pig iron. It has already been mentioned that 2 tons of extremely pure iron can be produced per kilowatt-year. Using a current of 500 amperes per square meter, instead of 1,000 amperes, the voltage drops to about one half, and the production per kilowatt-year is nearly doubled. Working with a still lower density, the yield can be even further increased. In countries where the cost of motive power is high, it would pay to work at 500 amperes or even less. It would then be possible to produce 3 to 4 tons, and even more, per kilowatt-year. If the cost of the unit be taken at 1 centime (0.1d.), an ordinary figure in the Alps, and using a current density of 1,000 amperes, the cost of current would not exceed 43 francs per ton of iron produced. Since pig iron is used as the raw material, it may be reckoned that there is about 10 per cent of waste in the form of sludge, graphite, etc. The price of the pig iron would vary according to the locality, and in the mountainous country it would run at about 64 to 88 shillings per ton. The price, however, would be higher in those localities where the electric current was cheapest, and *vice versa*. The average outlay on pig iron per ton of electrolytic iron would therefore be from about 72 to 80 shillings. To this would still have to be added the cost of labor, maintenance, cost of electrolyte, depreciation, and interest on the capital cost of the plant. These various amounts have not yet been definitely ascertained, but the total cost price, based on current prices for material and labor, of the electrolytic iron, in the condition in which it leaves the electrolyte bath, would probably not exceed £6 to £7 12s. per ton, according to the locality.

COMMENTS BY SHERARD COWPER-COLES.

The secretary of the Iron and Steel Institute makes public the following as the substance of a communication sent to him by Sherard Cowper-Coles of Sunbury-on-Thames, England, in which exceptions are taken to some statement in Prof. Guillet's paper:

Mr. Sherard Cowper-Coles wrote that he considered



Commercial tubes of electrolytic iron.

possible to work with a current of high density (1,000 amperes to the square meter), and an iron of excellent quality is obtained. The process is applicable either to the production of very pure iron, which can compete with the best iron and Swedish iron, or to the direct manufacture of tubes and sheets in the finished state. It has emerged from the laboratory stage, and is now being put into operation on an industrial scale.

PROPERTIES OF THE METAL.

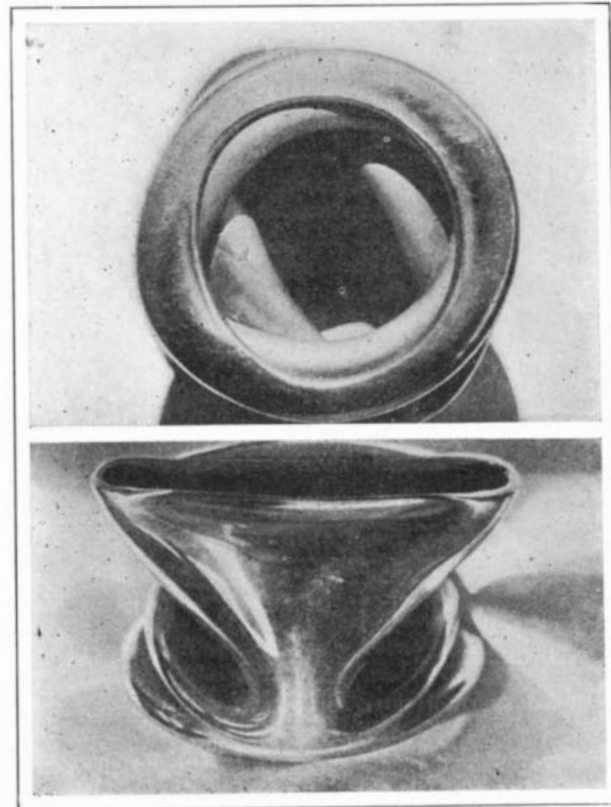
Using any pig iron in solution, an electrolytic iron can be obtained of the following average composition, after removal of the gases by annealing:

	Per Cent.
Carbon	0.004
Silicon	0.007
Sulphur	0.006
Phosphorus	0.008

At the present time it is possible to guarantee phosphorus lower than 0.010 per cent. With a density of current of 1,000 amperes per square meter, the yield per kilowatt-year is 2 tons of metal, including the cost of current for the accessory services, particularly for the rotation of the cathodes.

The material in the crude state, that is, in its state on removal from the electrolyte bath, is hard and brittle.

* From a paper prepared for the abandoned fall meeting of the Iron and Steel Institute at Paris. The author is professor of metallurgy at the Conservatoire National des Arts et Métiers, Paris. Reproduced by courtesy of *The Iron Age*.



Result of crushing tests on electrolytic iron tubes.

the paper by Mr. Guillet very misleading in some of its statements. In 1908 he (Mr. Cowper-Coles) read a paper before the Iron and Steel Institute entitled "The Production of Finished Iron Sheets and Tubes in One Operation," describing in considerable detail his electrolytic process for the direct production of iron tubes, cylinders, and sheets. In that process a mandrel revolving at a critical speed, so as to give sufficient skin friction between the electrolyte and deposited metal was employed to obtain a close homogeneous deposit and at the same time enable a high current density to be employed, the solution being kept neutral by bringing it in contact with iron oxide as described in Mr. Guillet's paper. In the following year, Mr. Boucher approached him (Mr. Cowper-Coles) regarding the process and asked if he would grant him a license to work it in France and Switzerland. This was done, and a small trial plant was thereupon set up in Switzerland and Mr. Boucher produced a number of tubes. A company was ultimately formed, called Le Fer, to acquire the license that had been granted to Mr. Boucher.

Mr. Cowper-Coles's object in setting out these facts is to show that all the preliminary work was carried out in Great Britain at great expense and much labor. That that was so could hardly be gathered from what he thought was a somewhat ungenerous statement which constituted the only reference to the process in Mr. Guillet's paper:

"In 1907 Mr. Cowper-Coles took out a patent involving the use of a 20 per cent solution of sulphocresylate of iron and endeavored to manufacture weldless tubes, using a rotating cylindrical mandrel. This process which was analogous to the Elmore process for making copper tubes has not yielded results of much importance."

The Cowper-Coles process, he continued, is in no way analogous to the Elmore copper process which consists in using an agate burnisher. He thought it should be known that the process described in Mr. Guillet's paper had been worked out in England, and that works are to be erected in the Midlands to carry out the process on a commercial scale. He (Mr. Cowper-Coles) had all the necessary documents for proving the statements he had given.

Business Aspect of the Kelp Proposition*

By Frederic P. Dewey

It is thoroughly well established that the giant kelps of the Pacific provide an enormous store of KCl. Various papers have appeared upon the broad, general aspect of the question, but for the most part they have dealt in glittering generalities and many of them have started in the middle of the proposition. Many writers neglect or slur over the gathering and preliminary drying of the kelp, and base their real consideration of the subject upon the air-dried material. This is very attractive and easy to do, but the cost of the air-dried kelp is a most serious business consideration.

There are various technical and business problems connected with the matter. Without in the least doubting the eventual solution of these problems, it may be said with entire safety that their solution with financial profit will require the expenditure of much time and money, under the best technical and business direction, and that it must be several years before KCl from kelp can become a commercial commodity, if it ever does.

The consideration of the subject divides itself naturally under the following heads:

- Harvesting the kelp.
- Air-drying.
- Oven-drying.
- Distillation.
- Crystallizing KCl.
- Marketing.

To start with the growing kelp. How can it be harvested?

It will be an entirely new industry and manifestly various machines of different types will have to be constructed and subjected to actual practical tests before an efficient and economical machine is secured. Dr. Cameron has suggested 1,000,000 tons of KCl as a conservative annual yield. This would mean the harvesting of approximately 30,000,000 tons of kelp. This harvesting cannot extend over the whole year. Just how long it may last cannot yet be definitely known, but in any event the vast machinery required to harvest 30,000,000 tons in a short season must stand idle a good part of the year at a heavy interest charge against the product.

Having brought the kelp to shore it must be dried. To produce a ton of KCl, approximately 27 tons of water must be evaporated. Clearly the most inexpensive natural means for drying must be adopted, but even this would require the construction of drying sheds

covering an enormous area and the building of especially designed machinery to distribute the wet kelp on the drying shelves and to gather up the dried stuff. As with the harvesting machinery, these sheds and machinery must remain unemployed a good part of the year.

There is, however, a limit to the extent that natural drying in open sheds can be carried. When about 25 tons of our 27 tons of water have been evaporated, provision must be made to protect the efflorescing KCl which will soon be produced on further drying. This will require the application of artificial heat. It may possibly be assumed that this can be obtained from the kelp itself in a subsequent operation. By proper oven-drying it is possible to recover 40-50 per cent of the KCl as effloresced salt by simply shaking it off from the dried kelp.

The recovery of the balance of the KCl from the dried and shaken kelp requires the breaking up of the organic matter of the kelp body and this must be done with as full as possible utilization of its value. Simple burning with the utilization of its heat value only will not be sufficient, even if we now had a furnace adapted to avoid inclosing unburned material in the inorganic salts by sintering and to avoid undue loss of KCl by volatilization.

At present, there does not seem to be any method available for this part of the work except destructive distillation with the recovery of the condensable by-products and the utilization of the gas, first to heat the retorts, and secondly, for the oven-drying of the kelp as far as may be. Probably there are no technical difficulties in this operation, but it must be remembered that only about half of the weight, including the effloresced KCl, of the oven-dried kelp is organic matter. In other words, broadly speaking, in the production of one ton of KCl only one ton of organic matter is available for the production of by-products of distillation. On the other hand, the total production of such by-products in the recovery of 1,000,000 tons of KCl would be so large that much of them would have to be transported long distances to find a market and therefore the profit of the operation would largely depend upon freight conditions.

Undoubtedly a limited amount of the residue from the retorts could find direct application as a fertilizer within a certain radius, but the real market for KCl is on the Atlantic coast, and under the present freight conditions of 80 cents per 100 pounds the KCl must be dissolved and recrystallized. Upon the opening of the Panama Canal and the expected halving of the freight rates, the distillation residue might possibly better be shipped direct.

The mother liquors from the recrystallizing of the KCl will contain iodine and when sufficiently enriched they may be treated for the recovery of this element.

It would be a liberal estimate to assume that the by-products recovered, including the iodine, would have a value sufficient to pay for all of the operations upon the air-dried kelp. If we do this and also assume that after sufficient trial and development of the necessary machinery the kelp can be harvested for 25 cents per ton and air-dried for 15 cents per ton more, a ton of KCl laid down on the Atlantic coast would cost \$28 as follows:

Harvesting 30 tons at 25 cents	\$7.50
Air-drying 30 tons at 15 cents	4.50
Freight 1 ton at 80 cents per 100 pounds	16.00
	\$28.00

On the completion of the Panama Canal it is expected that the freight will come down to \$8 per ton, but the present prices of KCl must be very profitable to the German Potash Syndicate, and if actually faced with the possible loss of its American trade the prices would undoubtedly be reduced. This reduction might even wipe out the advantage of the low water-freight.

In conclusion it would appear that the feldspars have not yet been displaced by the kelps as a possible source of potash.

Parsons' Marine Turbines

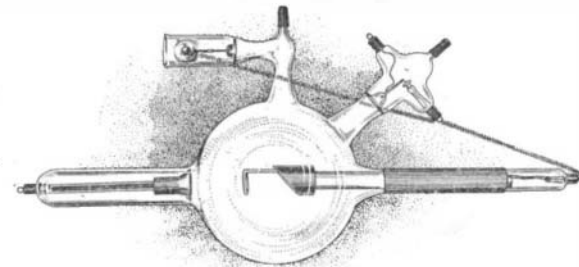
THE total horse-power of marine turbines of the Parsons type completed and under construction in England and elsewhere amounts to about 12,360,000 horse-power, an increase during the last 12 months of about 1,760,000 horse-power, according to a statement in the *London Times*. Of the total nearly 10,520,000 horse-power is, or will be, employed for the propulsion of warships, and over 1,850,000 horse-power in mercantile vessels and yachts. The use of geared turbine machinery for ship propulsion is extending rapidly, and 126 vessels built or building are wholly or partly fitted with such machinery, of an aggregate of about 1,000,000 horse-power. These include 62 vessels of 620,000 horse-power ordered during the past year by the Cunard, White Star, Canadian Pacific Railway, Union of New Zealand, Ellerman, and other lines.

New Hydrogen X-Ray Tube

By H. Clyde Snook

FOLLOWING extended research work in the Snook-Roentgen laboratories, at Philadelphia, Pa., comes the announcement of the development of a new type of X-ray tube, known as the hydrogen tube. Results from its use in a number of disinterested Roentgenological laboratories over a period of several months would seem to indicate that the new type of tube possesses important points of superiority over other X-ray tubes in use at the present time.

One of the most frequent and annoying defects in X-ray tube construction in the past has been the difficulty encountered in adjusting the vacuum to a satisfactory working condition. The most striking characteristic of the new hydrogen X-ray tube is found in the fact that it can be regulated either up or down as to vacuum both accurately and quickly.



The Snook-Kelly hydrogen X-ray tube.

The vacuum is lowered by means of the osmosis of chemically pure hydrogen through a metallic tube, closed at one end, which acts as an osmotic membrane when heated to redness. This metal tube is sealed into the main wall of the vacuum chamber, its open end communicating with the vacuum. Its closed end protrudes into a body of hydrogen contained within a small glass chamber attached to the bulb proper. The metal tube is heated to redness by passing the current across a short spark gap.

To raise the vacuum a similar tube within the raising attachment is heated to redness by the same means. Although, under normal working conditions, the hydrogen pressure within the vacuum (so called) is but .0001 to .000001 millimeter of mercury absolute pressure, it behaves according to the well-known principle that "gases act like vacuums to each other." Atmospheric air is excluded from the vacuum by the metallic tube—yet when the tube is heated, as described above, hydrogen is discharged osmotically into the atmosphere by its own pressure. Hydrogen in minute quantities, therefore, actually passes outward from the vacuum when the raising attachment is in operation. The vacuum of the tube is thereby raised in accordance with the length of time the operation is continued.

Roentgenologists report that the hydrogen tube displays marked stability and disinclination toward heating, due, presumably, to the fact that hydrogen possesses the lowest atomic weight of all known gases and displays little chemical avidity for most metallic substances. Extraordinary penetration has also been noted, comparative radiograms showing one Benoist number higher than with any other type of tube.

Greater efficiency, more uniform result, and longer life appear, therefore, to be the advantages of the hydrogen tube as demonstrated to date.

Simultaneously there has been evolved, in the same laboratories, an air-cooled type of hydrogen tube, with its vacuum subject to regulation by the same means as the standard type referred to above. By the use of the air-cooled hydrogen tube long fluoroscopic work may be punctuated by making radiograms and administering X-ray therapy in massive doses as frequently as the operator may desire.

The hydrogen tube is the result of joint work by Mr. H. Clyde Snook and Mr. Edwin W. Kelly.

Electro-chemical Generators

THE Neuhausen Aluminium Works recently ordered three electric generators for an increase in their large plant at Chippis in the Swiss region. These machines are built by the well-known Oerlikon Works, and are to be ranked among the largest yet to be constructed for electro-chemical use, being of 2,650 kilowatt size, or 3,850 horse-power. Such machines deliver as much as 8,000 amperes, at a tension of 340 volts, and the standard speed is 300 revolutions per minute. The generator in each case is direct coupled to a hydraulic turbine, and it is built to stand an overload up as high as 3,000 kilowatts, while if necessary the speed can be increased to nearly twice the standard, or to 540 revolutions per minute. As far as we know, the present machines appear to be not only the first to be built, at least in Europe for such a large output and as heavy a current with a relatively high speed, but appear even to be the largest generators yet to be built on this side for electro-chemical purposes.

* From the *Journal of Industrial and Engineering Chemistry*.