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DR. R. F. RUTTAN IN THE CHAIR.

MANUFACTURE OF CALCIUM CARBIDE.

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The commercial manufacture of calcium carbide, credited to Willson in America, and to Héroult in Europe, started in the early eighties, and by progressive development, has risen to become a consumer of electrical energy greater than any other electric furnace process. As is the case with all new industries, the beginnings were crude and inefficient. At present, although the proposition presents problems of some magnitude, the average of excellence is high, and the operation of numerous works is successful, from a commercial standpoint. The steadily increased demand for carbide resulted in increased size of furnaces, together with the electrical transformers necessary to their successful operation. The manufacturers of electrical apparatus have, therefore, been forced to design and build generators and transformers specially adapted to the need of electrical smelting.

The raw materials used in the manufacture of calcium carbide are lime and some form of carbon, such as anthracite coal or coke. Both these materials should be as pure as possible, special attention being paid to their freedom from phosphorus. Sulphur, magnesia, silica, iron, and alumina should be present in small quantities only.

Phosphorus occurs as calcium phosphate, which is reduced at the temperature of the electric arc, and in the presence of carbon, to calcium phosphide, which when brought into contact with water, gives off phosphoretted hydrogen. This gas mixes with the acetylene, and when burners are lighted, causes a haze of phosphorus pentoxide, which is very objectionable. So carefully, however, are the raw materials selected, that to-day, all commercial carbides are practically free from phosphorus, the average content of phosphine in acetylene being less 0.002 per cent. by volume.

Sulphur, unless present with considerable amounts of alumina, has little influence in the carbide. Calcium sulphide formed in the furnace by the reduction of calcium sulphate, does not decompose in the water. In the presence of alumina, aluminium sulphide may be formed; this yields hydrogen sulphide when brought into contact with water. Practically speaking, very little trouble is experienced with sulphur, inasmuch as the lime and coal used rarely contain a prohibitive quantity.

Magnesia has the peculiar property of interfering with the formation of calcium carbide in the furnace. If more than 1 per cent. of magnesia be present in the lime and coal, the electrical energy required becomes noticeably so much greater, that such raw material is considered unfit for use. To counteract its effect a flux of fluorspar has been recommended by some authorities. In the experience of the writer, this is not very successful. It is well known that magnesia mixed with carbon and treated in the electric furnace, will not form a carbide, and is highly infusible, even at the highest temperatures obtainable. Metallic magnesium heated in a current of acetylene, however, readily forms magnesium carbide.

Barium and strontium form carbides with ease when their oxides or carbonates are reduced under similar conditions with carbon at electric furnace temperatures.

Silica, iron oxides, and alumina form silicates, aluminates, and ferro-silicon, which reduce the purity of the carbide, and its output from the furnaces.

The presence of water, either in the free state in the coal or combined as hydroxide in the lime, is the greatest difficulty the carbide maker has to contend with, as it reduces the furnace output more than any other factor. For this reason, the coal is thoroughly dried, usually in a rotary coal- or gas-fired dryer. The lime should be burned in kilns at the carbide works, and fed direct to the electric furnace to secure the best results.

The preparation of the charge for the furnaces. The lime is roughly crushed to pieces of one inch size, the coal, thoroughly dried, to about pea size. They are then roughly mixed in about the theoretical proportions called for by the equation, $\text{CaO} + 3\text{C} = \text{CaC}_2 + \text{CO}$, or approximately 100 parts by weight of the lime contents of the lime to 65 parts of the carbon contents of the coal or coke.

In the early history of the industry, it was believed necessary that both the lime and the coal should be ground very fine, and thoroughly mixed, in order to secure uniform results in the quality of the carbide. This fine grinding, however, caused the furnace to blow out large quantities of dust, which upset the proportions of the mixture, frequently producing very irregular results. With experience in operation, and particularly with furnaces of increased size, the fine grinding was abandoned, until at the present time, lime as large as eggs is used in some furnaces; the coal, however, is kept about $\frac{1}{2}$ in. mesh. In this way the dust losses from the furnaces are decreased to a minimum, the actual output and quality of the carbide being at the same time improved. In other electric furnace processes the same change has been effected, and the prevailing practice is to use coarsely ground raw material, which offers little resistance to the free escape of the furnace gases.

Electric furnaces for the manufacture of carbide can be divided into two types, the ingot furnace, in which the carbide is allowed to solidify, and the tapping furnace, in which the product is run in the molten state in the same manner as iron. At first, carbide was made entirely in the ingot furnaces, on account of the difficulty of attaining a temperature sufficient to melt it thoroughly.

The simplest form of ingot furnace is the Borchers, or pot furnace, in which some form of iron crucible is lined on the bottom with a layer of carbon, this being connected to one side of the electrical circuit. The other terminal of the circuit is connected to a carbon rod held in a suitable holder, which is suspended vertically in the centre of the crucible, and adjustable up and down within it. To accomplish this, some form of hoist is used, as these carbon rods and holders are heavy, weighing sometimes nearly a ton. To start such a furnace, the moving electrode is lowered to contact with the carbon bottom forming an arc: the mixture of lime and coal, previously prepared and usually stored in a bin above the furnace, is fed in around the arc and entirely covering it. An ammeter in the circuit indicates the current used, and the hoist is raised or lowered, often by automatic relays, to keep the current at a constant figure. The early Willson furnaces used in America used a current of 2000 ampères and 75 volts. The arc so started and burned in the charge smelts a pool of carbide, which gradually deepens, necessitating frequent lifting of the electrode, until the crucible is filled. The crucible is then wheeled out, and an empty one substituted. When sufficiently cool, these crucibles were dumped on a grating, the unconverted mixture going through the grates to a recovery storage bin, and the ingot itself taken to a clearing room. Here the crust or scale was removed by the use of axes or pneumatic tools. This process was unsatisfactory from the standpoint of uniform quality of product and cost of production. A large quantity of lime and coal surrounding the ingot was unconverted, and therefore had to be rehandled. A considerable quantity of coal was burned out in the

operation of dumping the pots, necessitating further addition of coal before the mixture could be used again. In practice 4 tons of raw materials were handled to make one ton of carbide. The ingot itself varied from almost pure carbide in the centre, where the heat of the arc was greater, to an outside layer of melted lime and coal which had not become sufficiently hot to be converted into carbide. The removal of this outside layer was often difficult and frequently the crust was found in the carbide, causing much dissatisfaction.

At this stage the American makers began to use a very ingenious furnace to offset these difficulties. This is known as the Horry rotary furnace, and while still adhering to the ingot principle, it has been so perfected, both in operation and efficiency, that it competes successfully with any other process.

The body of the furnace is formed like a spool with wide flanges fastened to the drum, thus forming with it three sides of a square if viewed in cross section. The fourth side is formed by removable plates, which are clamped across the ends of the sides or flange plates by use of bolts or clamps. Two electrodes, suspended from above, hang vertically in this square space. There is no electrical connection made to the furnace itself, the current passing from one electrode to the bath of carbide, and through the carbide to the second electrode. The furnaces are therefore known as two-electrode single-phase, and use a current of about 4000 amperes at 75 to 80 volts. In operating this furnace, a small quantity of broken coke or carbon is placed under the electrodes, the arc sprung, and the charge of lime and coal fed in until the arcs are well covered up. The electrodes themselves are fixed, the regulation being accomplished by slowly revolving the drum away from the arc as the carbide accumulates in a pool beneath the electrodes. This regulation is automatic, being controlled by a relay which engages a pawl to increase or decrease the current by revolving the furnace to the right or left. The revolution of the furnaces is very slow, the movement at the circumference being about 6 inches per hour.

The ingot so formed passes slowly downwards from the electrodes under the axle of the furnaces and upwards at the back. In the rear the end plates are unbolted and the carbide ingot exposed. Holes are drilled across the ingot by compressed air drills with water cooled points, the water cooling the carbide and slaking it in front of the drill. Into the holes so formed, wedges are driven and a section of the ingot broken off and carried away by a crane to the cooling room.

The operation of these furnaces is continuous during the life of the electrodes, which, being kept well buried in the charge, are consumed very slowly. The actual fusion of the carbide extends very close to the cast-iron sides of the furnaces, thus minimising the quantity of unconverted charge and crust.

Two other electrode furnaces having a crucible instead of the revolving wheel are also in use. These differ in principle from the rotary furnaces only in not being continuous, the crucibles being changed when full, and new ones substituted every 10 and 12 hours.

The tapping furnace.—In Europe the early pot furnaces of the ingot type were slowly changed to tapping furnaces, in which the carbide was heated to sufficient temperature to run out in the molten state into cast-iron moulds. The type of furnace used was much the same as the ingot pot furnaces, with a single electrode suspended in the centre of the pot, which latter was lined at the bottom with carbon and provided with a suitable connection to the other side of the circuit. One of the greatest difficulties to contend against was actual maintenance of the carbide at a temperature at which it could run readily from the furnace. To meet this a flux of lime was added which increased the fluidity, but somewhat reduced the quality of the carbide.

With the developments of larger transformers larger furnaces were built. Also skill in the art of tapping the furnaces played no small part in their ultimate success. At the present time, carbide is tapped easily at the

highest temperature, and the grade of the material so made is fully equal to the best ingot product.

Later developments in tapping furnaces tend towards two or three electrodes suspended vertically in the furnace, using two- or three-phase current to distribute more equally the load to suit the necessities of the generating plants. Such furnaces can be built to large sizes of 2000 to 3000 h.p. and even more, with great economy gained from the labour and power standpoint.

The manufacture of suitable furnace electrodes has been the deciding factor in many cases. Often manufacturers of carbide were unable to use furnaces because no satisfactory electrodes could be had. In 1892 the only satisfactory electrode made in the United States was 4 inches square, and would carry about 500 amperes. To-day, electrodes 18 inches to 22 inches are in the market, which are satisfactory and reliable. Even larger electrodes are advertised capable of carrying very heavy currents. Electrodes made by assembling a number of 8-inch diameter units in parallel in a single head or holder, have been in successful use at Shawinigan Falls for a number of years. Currents up to 40,000 amperes are occasionally used, with 25,000 to 30,000 amperes the average load.

With reference to the use of graphitised electrodes, there is a great difference of opinion, the ingot makers using graphite, whereas those using the tapping process prefer the amorphous carbon electrodes. The writer, in using both, found that the graphite consumed too rapidly in the tapping furnace, making the cost prohibitive, so the amorphous carbon electrodes were adopted on account of their cheaper price. This is easily understood when it is considered that the ingot makers use an excess of carbon in the furnace charge, while the tapping furnace requires a slight excess of lime.

Whether the carbide itself is made by the ingot or tapping process, its subsequent treatment is much the same. The ingot carbide possesses the disadvantage of having to be freed from scale or crust.

The problem of crushing and sizing is one of successive reduction through crushers and rolls, making the least possible dust. Ingot carbide has a natural tendency to break into cubes on account of its crystalline structure caused by the slow cooling of the ingots. Tapped carbide, on the contrary, is cast at approximately 2500° C. into a heavy cast-iron chill, and is consequently close grained and dense. It is much harder to break and requires very strong machinery. For the first breaking, jaw crushers of the Blake type are common, although some makers prefer gyratory crushers. For granulation of carbide to sizes of $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch, low speed rolls are used, as these machines make the minimum amount of dust. The sizing is usually done on trommels or rotary screens, which deliver the product in sizes varying from large lumps, 8 inches by 4 inches, to fine materials, 16 by 30 mesh, suitable for a certain type of table lamp.

A can-making plant is a necessary part of every works, where steel and tin air-tight receptacles are turned out in large quantities to hold the carbide. The standard packages in use hold 100 lb., 110 lb., and 220 lb. net weight of carbide. Small tins containing from 1 to 25 lb. are also filled to suit the trade for automobile lamps, etc. All carbide which is exported by water is subject to rigid insurance rules, which necessitate the steel drum being cased in wood. A complete installation of box and stave-making machinery is therefore part of the equipment of every export works.

The largest use for carbide is in the generation of acetylene for lighting purposes, and this business steadily advances from year to year, showing the satisfaction that is experienced in the use of this beautiful light. The oxy-acetylene blowpipe is becoming a common tool in well-equipped shops, and in the hands of skilled operators gives great economy in repairing broken parts and in cutting away unnecessary metal. The cyanamide industry in Europe is believed to be on a sound financial basis, and is now using thousands of tons annually. The decomposition of the cyanamide and the formation of ammonium sulphate has also been undertaken.