resistivity of molten steel is an important factor; and this is very small, being about 0.00008 ohm for one cubic inch.

ELECTRODES.

With very few exceptions, the electrodes, which serve to lead the electric current into the furnace, are composed of carbon. They are made from retort carbon, petroleum coke and coal tar, the pulverized carbon being mixed with tar and pressed through a die of the required shape and size. The electrodes are then subjected to a baking process, which drives off the volatile part of the tar, and leaves them a hard, compact mass of carbon. Graphitized electrodes are made in like manner from petroleum, coke, and tar, with the addition of 1½% or 2% of hæmatite; being heated in an Acheson furnace to a very high temperature. The iron which is contained in the hæmatite, effects the conversion of the carbon into graphite, and is finally expelled, by volatilization, at the extremely high temperature of the furnace; leaving the electrodes composed of compact graphite. Molten iron has the property of dissolving carbon, which separates from the iron as graphite on cooling; but it is difficult to understand how so small a proportion of iron can change the whole electrode into graphite.

Graphitized electrodes have the advantage of purity, good conductivity, and great resistance to oxidation.

Their purity renders them very advantageous in operations like the production of aluminium, in which the electrode ash enters the electrolyte, and contaminates the resulting metal. The characteristic resistance of these elecrodes to oxidation, reduces their consumption, and their good conductivity has a similar effect, since smaller electrodes can be employed. Graphitized electrodes are largely used for electrolysis, but, in electric smelting furnaces, cheaper ones made of coke and tar have usually been employed; while in some cases the coke forming part of the furnace charge has been utilized for leading in the current; electrical contact being made through the charging hoppers. The kind of electrode to be employed will depend largely upon the oxidizing or reducing character of the furnace. In the former case the graphitized electrodes would be preferable, while in the latter, the ordinary kind would serve the purpose.

Approximate figures, for the resistivity of carbon and graphite electrodes, have already been given. By means of these, it is easy to calculate the drop of voltage that would be produced in electrodes of a certain length and cross section, by any particular current. The cross section of an electrode is usually determined by the amount of current to be carried. The current density or the number of amperes per square inch of cross section of the electrode, differs considerably in different types of furnaces and for different kinds of electrodes, being much higher in graphitized electrodes than in the ordinary variety. The large electrodes used in the Héroult and Keller furnaces carry about 20 amperes per square inch, while small round electrodes and graphite electrodes carry more, up to about 100 amperes per square inch. Moissan used currents up to 200 or even 700 amperes per square inch, in small, ungraphitized electrodes, but this would be far too high for commercial work, as the carbons would become red hot and would rapidly waste away, and the consumption of electrical energy, in the electrode, would be too high to be tolerated. The loss, by oxidation, of the exposed part of an electrode, can sometimes be prevented by a system of water jackets, as in the Héroult steel furnace, Fig. 25.

The only furnaces in which some form of carbon electrode is not employed, are the electrodeless furnaces, such as the Kjellin steel furnace, and furnaces in which metallic electrodes, usually water cooled, are employed. Examples of these are the Gin steel furnace, the Laval ore-smelting furnace, and Borcher's aluminium furnace.

ELECTRODE HOLDERS.

Electrode holders are employed for making electrical connection between the electrode and the cable which supplies the electric current. They are also used for supporting and manipulating movable electrodes. The holders are made of copper or bronze, which are preferable on account of their good electrical conductivity, or of iron or steel, which are cheaper and do not melt so easily if over-heated. It is not easy to maintain a thoroughly good electrical contact between the holder and the carbon electrode, because the electrodes and their holders become heated, and the expansion of the metal loosens its hold on the carbon. The relatively poor conductivity of the carbon makes a large area of perfect contact desirable, while the small mechanical strength of carbon renders it difficult to clamp the holder sufficiently tightly without breaking the electrode. In addition to this, the heat of the furnace tends to render unworkable any bolts and nuts or similar mechanical devices.

Graphitized electrodes can be easily machined or threaded, and attached in this way to the holder; but for electric smelting furnaces, electrodes of rectangular cross section are more usually employed, and these are secured in their holders by bolting or clamping. The electrodes, in smelting furnaces, are usually vertical, in order to be more easily manipulated, and are suspended by a chain, so as to be easily raised or lowered; the electric cable being attached directly to the electrode holder. The holder shown in Fig. 22 may be taken as an example. The part A is made of steel, and the descending jaws JJ fit into the sides of the electrode, and are prevented from spreading by the two bolts. The electrode is driven downward by wedges, thus making good contact with the jaws. The upper part B is made of sheet copper, and enables the electric cable, and the pulley and chain by which the electrode is suspended, to be placed so far above the furnace, that they will not be overheated, while the lower part A can be cooled by air or water introduced from above. The electrodes of the Heroult steel furnace are supported by arms from the back of the furnace, instead of by chains; this construction being better adapted to a tilting furnace. The electrode is square in section, and is surrounded by four contact pieces, one for each side. One of these pieces is attached to the arm and the other three are tightened against the electrode by a steel strap, which encircles them, and is drawn tight by a screw contained within the arm.

The holder is shown in outline, Fig. 26. AA is the arm with tightening screw, S and nut N, to which is attached the strap F, which draws the contact pieces B C and D against the electrode E, and the latter against the arm A. A cable, not shown in the sketch, is bolted to A and to B C and D, thus distributing the current to the movable electrodes. A shield is provided to protect the holder from the heat and smoke of the furnace.

The iron and steel making furnaces, Figs. 22 to 25, will be further described in Article No. 5 together with some additional discussion of the construction and operation of such furnaces.

NIAGARA A GREAT WORKSHOP.

The Niagara Falls are rapidly assuming the nature of a huge chemical laboratory, and the employment of the electrical furnace for the production of various metallurgical and chemical products at these waterfalls appears to be extending almost day by day. It has been shown that a commercial efficiency of some 75 per cent. can be readily obtained from moderately-sized electric furnaces, and there is no reason to doubt that this efficiency can be enlarged. Aluminium, as is generally known, is one of the chief products of the electric furnace at Niagara; this is followed by calcium carbide, carborundum, and artificial graphite. Calcium peroxide is now being made, with the design of its employment as a sterilizing agent in the preservation of food. Magnesium peroxide is being produced for the same purpose. It is stated that an interesting use of caustic soda is being made at Niagara, where it is utilized for the production of sodium, which is converted in its turn into sodium peroxide. An American firm is now marketing tablets made from sodium peroxide, which are used for the production of oxygen, which gas is generated on the immersion of the cake of sodium peroxide in water in a way similar to the generation of acetylene from carbide of calcium. It is stated that one pound of the prepared material yields 59 litres, or 2.08 cubic feet of gas.