the metals and carbon are sufficiently conductive to carry large electrical currents; but, when heated to their melting temperature, most of the rock-forming minerals will carry an electric current; and when mixed in suitable proportions for a melting charge, and fused, they always form sufficiently good electrical conductors.

The conductivity of molten slags, enables continuous smelting furnaces to be operated electrically, although the ore fed into the furnace may be non-conducting. The furnace may be started in the first place by means of an arc between the electrodes: the heat of the arc melts some of the surrounding material, which ultimately fills the space between the electrodes with a molten conducting slag, in which heat continues to be generated by the passage of the current. More ore becomes heated and melted, and after a time the whole crucible of the furnace becomes thoroughly heated and filled with molten slag and metal. Another way of starting such a furnace is by placing some coke between the electrodes. This, being a moderately good conductor, soon becomes heated by the passage of the current, and melts the surrounding ore charge; after this, the electrodes are pulled further apart and the operation goes on as described above. A third method consists in pouring into the furnace a potful of molten slag, when the current may be at once switched on, and the furnace will soon be in regular operation.

Although the ordinary rocks and ore minerals are very poor electrical conductors, when cold, the coke, which is often added to the charge as a reducing reagent, is a fair conductor, and, if present in sufficient quantity, will render the charge somewhat conducting.

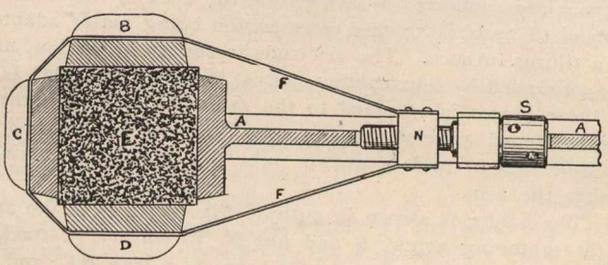

Fig. 26.—Electrode Holder of Heroult Steel Furnace.

Electrical Resistivity.—In order to design a furnace that will carry a certain electrical current at a given voltage, it is necessary to know the numerical value of the electrical resistivity of the materials through which the current will pass in the furnace. The Resistivity, or Specific Resistance of a substance, is the resistance, in ohms, between two opposite faces of a unit cube of the materials. A cube of one centimeter edge is usually referred to, but it is sometimes more convenient to know the resistance of an inch cube of the material. If the resistivity, or resistance of an inch cube of a substance, were **R** ohms, the resistance, between the ends of a cylinder of this material, **L** inches long and **C** square inches in cross section, would be $\mathbf{r\frac{l}{c}}$ The electrical resistance, in ohms, of any conductor, shows the voltage that would be needed to maintain a steady current of one ampere, through the conductor. Electrical conductivity is the inverse of resistivity, and shows the number of amperes that would be caused to flow through a unit cube if an electrical pressure, or electro-motive force of one volt, were maintained between two opposite faces of the cube. The unit of electrical conductance is the **Mho**; that is, **ohm** written the wrong way round.

Furnaces having Special Resisting Cores.—The cores or resistors in such furnaces are usually composed of carbon, which, in the form of coke powder, for example, is of moderate conductivity, thus allowing large currents to flow, and at the same time having a sufficient electrical resistivity to allow fairly high voltages to be employed—even when the cores are of considerable cross section and moderate length. The resistivity of powdered carbon depends upon the fineness of grain, as well as upon the resistivity of the solid material from which the powder was produced. In order to obtain uniform heating, it is advisable to sort powder, only using the particles that are of a uniform size; and under such conditions the resistivity increases with the fineness of the powder. The following resistivities for graphitized coke powder have been calculated from experiments by FitzGerald.* The resistivity of ordinary coke powder would probably be about four times as large.

Resistivity of Graphitized Coke Powder.

(Ohms for one cubic inch.)

Size of Grains.	Cold.	Red hot.	Red hot & weighed.
Between 5 meshes and 6 meshes to the inch.....	0.36	0.25	0.12
Between 3 meshes and 4 meshes to the inch.....	0.29	0.15	0.09

The first powder had been passed through a sieve having 5 meshes to the linear inch, and had been passed over a sieve of 6 meshes to the inch. The second powder had been passed through a 3 mesh sieve and over a 4 mesh sieve. The resistivities are given for the cold powder, and at a bright red heat. The third column shows the resistivity of the red hot powder when a weight was laid upon it, thus making a better electrical contact between the adjacent grains. The powder was placed in an open trough, and was only four inches in depth, and so would be more lightly packed than it would be in the core of a full-sized furnace. The figures in the list column would consequently more nearly represent regular furnace conditions. The figures are given for one cubic inch, as inches are still more frequently used, in this country, than centimeters; to convert to centimeter resistivities, multiply by 2.54—the number of centimeters in one inch.

For many purposes ordinary coke powder would form a better resistor than the graphitized material, on account of its higher resistivity; but it has this serious disadvantage, that if very strongly heated in the furnace the coke will become graphitized, and its resistivity will fall to about a quarter of its original value for corresponding temperatures. It will consequently be better, in high temperature furnaces, to use a core that has previously been graphitized, thus obtaining a more nearly constant material for the resistor.

Solid rods of carbon (amorphous or graphitized) are sometimes used as resistors, as in Borcher's resistance furnace (Fig. 14, page 214), or in Acheson's siloxicon furnace. The resistivity of rods of carbon, such as are used for electric lighting and furnace electrodes, and of the graphitized electrodes, is very much less than that of the same material in the form of a powder. The following are approximate values:

Resistivity of Solid Carbon.

(Ohms for one cubic inch.)

	Cold.	Hot.
Amorphous	0.0025	0.0012
Graphitic	0.0006	0.0003

In this table, "amorphous" refers to the ordinary carbon electrode, or arc light carbon; while "graphitic" refers to the graphitized electrodes. The word "hot" refers to electric furnace temperatures, such as 2,000 C. or 3,000 C., and it will be obvious that only approximate values can be given.

Furnaces in which the Current Passes through the Charge.

The writer has attempted to calculate the resistivity of the melting materials in the fusion zones of the Heroult and Keller ore-smelting furnaces, and also of molten slags themselves. The data available were very unsatisfactory, and the results obtained can only be taken as representing in the roughest way the resistivities of these materials. The Heroult and Keller smelting zones appear to have a resistivity of about 01. ohm for one cubic inch, varying perhaps from about 0.05 to 0.15 ohm. The resistivity of molten slag is less than this, being in the order of 0.01 to 0.05 ohm for one cubic inch. In the Gin and Kjellin steel furnaces, the

*Francis A. T. FitzGerald. Electro Chemical Industry, Vol. II. (1904), p. 490