

ART. XLI. — *On the Electrical Furnace and the reduction of the Oxides of Boron, Silicon, Aluminum and other metals by Carbon*; by EUGENE H. COWLES, ALFRED H. COWLES and CHARLES F. MABERY.*

THE application of electricity to metallurgical processes has hitherto been confined chiefly to the reduction of metals from solution, and few attempts have been made to effect dry reductions by means of an electric current. Sir W. Siemens endeavored to utilize the intense heat of an electric arc for this purpose, but accomplished little beyond fusing several pounds of steel. A

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short time since Eugene H. Cowles and Alfred H. Cowles, of Cleveland, conceived the idea of obtaining a continuous high temperature on an extended scale by introducing into the path of an electric current some material that would afford the requisite resistance, thereby producing a corresponding increase in the temperature. After numerous experiments that need not be described in detail, coarsely pulverized carbon was selected as the best means for maintaining a variable resistance, and, at the same time, as the most available substance for the reduction of oxides. When this material, mixed with the oxide to be reduced, was made a part of the electric circuit in a fire-clay retort and submitted to the action of a current from a powerful dynamo machine, not only was the reduction accomplished, but the temperature increased to such an extent that the whole interior of the retort fused completely. In other experiments, lumps of lime, sand and corundum were fused, with indications of a reduction of the corresponding metal; on cooling, the lime formed large well defined crystals, the corundum beautiful red, green and blue hexagonal crystals.

Following up these results with the assistance of Charles F. Mabery, Professor of Chemistry in the Case School of Applied Science, who became interested at this stage of the experiments, it was soon found that the intense heat thus produced could be utilized for the reduction of oxides in large quantities, and experiments were next tried on a large scale with a current from two dynamos driven by an equivalent of fifty horse-power. For the protection of the walls of the furnace, which were made of fire-brick, a mixture of the ore and coarsely pulverized gas carbon was made a central core, and it was surrounded on the sides and bottom by fine charcoal, the current following the lesser resistance of the central core from carbon electrodes which were inserted at the ends of the furnace in contact with the core. In order to protect the machines from the variable resistance within the furnace, a resistance box consisting of a coil of German silver wire placed in a large tank of water was introduced into the main circuit, and a Brush ammeter was also attached by means of a shunt circuit to indicate the quantity of current that was absorbed in the furnace. The latter was charged by first filling it with charcoal, making a trough in the center and then filling this central space with the ore mixture, which was covered with a layer of coarse charcoal. The furnace was closed at the top with fire-brick slabs containing two or three holes for the escape of the gaseous products of the reduction, and the entire furnace made air-tight by luting with fire-clay. Within a few minutes after starting the dynamo, a stream of carbonic oxide issued through the openings, burning usually with a flame eighteen inches in height.

The time required for complete reduction was ordinarily about an hour.

The furnace at present in use is charged in substantially the same manner, and the current is supplied by a Brush machine of variable electromotive force driven by an equivalent of forty horse-power. A Brush machine capable of utilizing 125 horse-power, or two and one-half times as large as any hitherto constructed by the Brush Electric Company, is being made for the Cowles Electric Smelting and Aluminum Company, and this machine will soon be in operation. Experiments already made show that aluminum, silicon, boron, manganese, magnesium, sodium and potassium can be reduced from their oxides with ease. In fact there is no oxide that can withstand temperatures attainable in this electrical furnace. Charcoal in considerable quantities is changed to graphite; whether this indicates fusion or solution of carbon in the reduced metal has not been fully determined. As to what can be accomplished by converting enormous electrical energy into heat within a limited space, it can only be said that it opens the way into an extensive field for pure and applied chemistry. It is not difficult to conceive of temperatures limited only by the capability of carbon to resist fusion. The results to be obtained with the large Brush machine above mentioned will be of some importance in this direction.

Since the cost of the motive power is the chief expense in accomplishing reductions by this method, its commercial success is closely connected with the cheapest form of power to be obtained. Realizing the importance of this point the Cowles Electric Smelting and Aluminum Company has purchased an extensive and reliable water-power, and works are soon to be erected for the utilization of 1200 horse-power. An important feature in the use of these furnaces, from a commercial standpoint, is the slight technical skill required in their manipulation. The four furnaces in operation in the experimental laboratory at Cleveland are in charge of two young men 20 years of age who, six months ago, knew absolutely nothing of electricity. The products at present manufactured are the various grades of aluminum bronze made from a rich furnace product that is obtained by adding copper to the charge of ore, silicon bronze prepared in the same manner, and aluminum silver, and alloys of aluminum with several other metals. A boron bronze may be prepared by the reduction of boracic acid in contact with copper.

As commercial results, may be mentioned a daily production in the experimental laboratory averaging fifty pounds of 10 per cent aluminum bronze; and it can be supplied to the trade in large quantities at prices based upon \$5 per pound for

the aluminum contained, the lowest market quotation of this metal being at present \$15 per pound. Silicon bronze can be furnished at prices far below those of the French manufacturers.

The alloys, which the metals obtained by the methods above described form with copper, have been submitted to careful study. An alloy containing 10 per cent of aluminum and 90 per cent of copper forms the so-called aluminum bronze, with a fine golden color, that is retained in the atmosphere for a long time. The tensile strength of this alloy is usually given as 100,000 pounds to the square inch; but castings of our 10 per cent bronze have stood a strain of 109,000 pounds. It is a very hard, tough alloy, with a capacity to withstand wear far in excess of any other metal in use. All grades of aluminum bronze make fine castings, taking very exact impressions, and there is no loss in remelting as in the case of alloys containing zinc. The 5 per cent aluminum alloy is a close approximation in color to 18 carat gold and does not tarnish readily. Its tensile strength in the form of castings is equivalent to a strain of 68,000 pounds to the square inch. An alloy containing 2 or 3 per cent aluminum is stronger than brass, possesses greater permanency of color and would make an excellent substitute for that metal. When the percentage of aluminum reaches 13 an exceedingly hard, brittle alloy of a reddish color is obtained; and higher percentages increase the brittleness and the color becomes grayish-black. Above 25 per cent the strength again increases.

The effect of silicon in small proportions upon copper is to greatly increase its tensile strength. When more than 5 per cent is present the product is exceedingly brittle and grayish-black in color. It is probable that silicon acts to a certain extent as a fluxing material upon the oxides present in the copper, thereby making the metal more homogeneous. On account of its superior strength and high conductivity for electrical currents, silicon bronze is the best material known for telegraph and telephone wire.

The element boron seems to have almost as marked an effect upon copper as carbon does upon iron. A small percentage in copper increases its strength to 50,000 or 60,000 pounds per square inch without diminishing to any extent its electrical conductivity.

Aluminum increases very considerably the strength of all metals with which it is alloyed. An alloy of copper and nickel with a small percentage of aluminum, called Hercules metal, withstood a strain of 105,000 pounds and broke without elongation. Another grade of this metal broke under a strain of 111,000 pounds with an elongation equivalent to 33 per cent. It must be remembered that these tests were all made upon castings of the alloys. The strength of common brass is doubled by the addition of 2 or 3 per cent of alumi-

num. Alloys of aluminum and iron are obtained without difficulty; one product was analyzed containing 40 per cent of aluminum. In the furnace, iron does not seem to be absorbed readily by the reduced aluminum when copper is present; but in one experiment a mixture composed of old files 60 per cent, nickel 5 per cent, and of 10 per cent aluminum bronze, 35 per cent was melted together and it gave a malleable product that stood a strain of 69,000 pounds.

When the reduction of aluminum is conducted in the absence of other metals it forms a compound with carbon analogous to pig iron as it comes from the blast furnace; and products are frequently analyzed that contain sixty or seventy per cent of aluminum. If the ore contains silicon the latter is absorbed by the aluminum and compounds of the two elements containing ten or fifteen per cent of silicon are often taken from the furnace in considerable quantities. These important products are at present under examination.