heat and reduce the descending ore. The use of the gas to preheat the ore before charging into the furnace is very desirable, but there will be no need to blow gases through the smelting shaft, because reducing gases are always formed here in large amount, and because the combustion of the gas in the calciner would heat the ore to a temperature at which it would begin to be reduced to the metallic state directly it was introduced into the smelting shaft.

Mr. Henri Harmet has written a treatise on the electro-metallurgy of iron, which is printed in Dr. Haanel's European report, and in this he considers every conceivable way in which iron ores can be reduced by the joint use of carbon and electrical heat, but no mention is made of any actual furnace embodying his views—even on an experimental scale.

In the Héroult and the Keller furnaces, which have successfully smelted iron ores on a small working scale, no use has been made—as far as the writer is aware—of the combustible gas, very rich in carbon monoxide, which escapes from the smelting shaft; though Keller intends to employ them for drying the ore. Attempts were made by Héroult in the experiments at Sault Ste. Marie, to utilize these gases by blowing air into the furnace near the top of the shaft, thus burning the gas and heating the descending charge. The arrangement could hardly be expected to work well, as the coke or charcoal and the carbon electrode were also exposed to the blast of air, and the ore was found to become

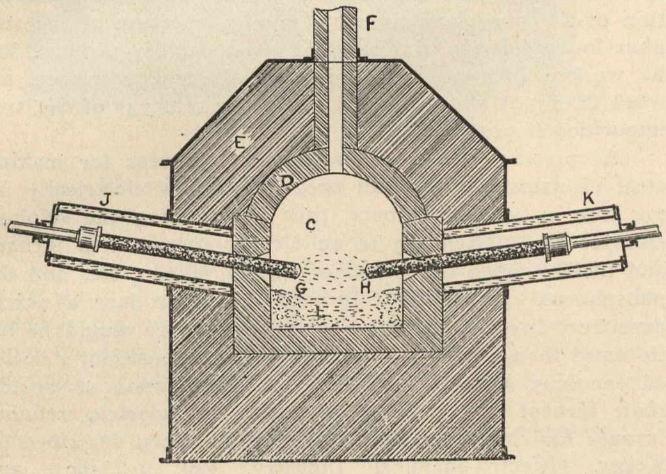

Fig. 24.—Stassano Furnace.

sticky, and not to descend regularly in the furnace. A considerable economy can, however, be made by utilizing the gases which at present escape from the electric smelting furnace, and until this has been effected it will be premature to limit the efficiency of the furnace, as it may be possible to obtain pig iron from the ore with a far smaller expenditure of electrical energy than Héroult or Keller have so far obtained.

Collecting the results that have been obtained in the electrical production of pig iron from the ore, it may be stated that the process is technically successful, and gives better results than the blast furnace in regard to the use of sulphurous ores, titaniferous and similar refractory ores, and ores in a state of powder, such as iron sand or ores which have been concentrated by magnetic or similar processes. The process also allows of the use of inferior and, therefore, cheaper fuel. The power required is about ¼ of a horse-power year, depending on the richness of the ore, and will probably be reduced to a decidedly lower figure. The fuel used for reducing and carburizing the iron is 700 or 800 lbs. of coke per ton of pig, or 800 to 1,000 lbs. of poor charcoal. These figures are also capable of reduction.

Comparing the cost of smelting by the two processes, apart from considerations of scale working, which will at first greatly hamper any electric smelting project, the main items of cost to compare are the fuel and the electric power. Thus in the electric furnace the ton of pig would require, at present, ¼ horse-power year and 700 or 800 lbs. of coke, while the blast furnace would require some 1,900 or 2,000 lbs. of coke. Balancing the cost of ¼ horse-power year against the cost of the coke that is saved, will give a general idea of the prices of coke and power which would permit of electric smelting. Of the other expenses of the two methods, the electric furnace, receiving high voltage current at a certain price, would require transformers and heavy cables from these to the furnace. The carbon electrodes must also be supplied. The blast furnace, on the other hand, has the expense of the blowing engines with their attendant boilers, and of the enormous hot blast stoves for preheating the blast, which will probably at least equal the cost of electrodes, etc., for the electric furnace, when the latter is operated on a fairly large scale.

The furnaces constructed by Héroult and by Keller are so very small in comparison with a modern blast furnace that the general expenses would tell very much more heavily on the electric process. These furnaces moreover could not very easily be largely increased in size, and obviously need a number of improvements before they reach their most satisfactory and economical design These improvements will, no doubt, accompany a gradual increase in size, and the electric smelting of iron ores will probably become a commercial fact in localities favorable to its operation.

III.—The Direct Production of Steel from Iron Ore.

It is quite possible to produce malleable iron or steel directly from the ore by heating the ore with a limited amount of carbon, enough to reduce the oxide of iron to the metallic state, but without the excess of carbon, which must unite with the reduced iron to make pig iron. The primitive metallurgists obtained wrought iron and steel by reducing the ore in small furnaces, instead of first making pig iron and then turning this into wrought iron or steel as is the present practice. Iron, nearly free from carbon, is, however, very difficult to melt, and in the little forge or furnace of the savage the iron was not melted, but obtained in the form of a solid lump, which was then cut up and hammered into shape; it being often necessary to pull the furnace down in order to extract the bloom of reduced iron or steel. With larger blast furnaces it is possible to melt even pure iron, but the melted iron will rapidly absorb carbon from the fuel employed, and so will become pig iron. It follows from this and other reasons, that wrought iron and steel cannot be made in a blast furnace. In the electric smelting furnace, however, the conditions are different, because, as the heat is supplied electrically and is not dependent upon the burning of fuel, the amount of carbon supplied can be adjusted exactly to suit the chemical needs of the ore, so as to make a carbon—free iron, or any desired grade of steel.

Captain Stassano has effected this in his electric arc furnace (Fig. 24), which resembles an open-hearth steel furnace, the flame of burning gas being replaced by the flame of the electric arc. The furnace consists of an iron casing lined with fire-brick E, and with an inner lining of magnesite bricks, D. An arc is maintained between the ends G and H of two, nearly horizontal carbon electrodes, the holders of which work through air-tight stuffing boxes in water cooled casings, J and K, thus preventing escape of furnace gases, cooling the holders and preventing the oxidation of the external portions of the electrodes. The necessary amount of carbon for making iron or steel is incorporated with the ore in the form of briquettes, which are introduced into the furnace, and heated until the chemical reactions have taken place and the reduced metal has melted. The metal and slag are then tapped out and the operation repeated. The carbon monoxide, resulting from the reaction of the carbon and the ore, escapes from the furnace by the hole F. This waste gas might be employed for drying and preheating the ore.

Dr. Haanel was unable to see Stassano's furnace at Turin in operation, as it was out of repair at the time of his visit, but he gives a description of the furnace and prints an account of the process written by the inventor. The newer forms of furnace are inclined about 7° from the vertical and rotate slowly round this inclined axis, with a view to stirring up the charge and allowing the heat of the arc to act more freely on the ore. Sometimes three electrodes are used, with three-phase current, and sometimes four electrodes are employed. Stassano gives the following particulars with regard to a furnace of 1,000 H. P. The cost of furnace is $5,000, the output per day is 4 or 5 tons, a cur-