of combining with nitrogen may enable it to remove this gas from the molten metal, and in this way to improve its quality.

The manufacture of ferro-nickel, ferro-chrome and other alloys of iron that are used in the production of steel are described by O. J. Steinhart.‡ Ferro-chrome, containing from 50 to 60 per cent. of chromium, was made at one time by heating chromite with charcoal in crucibles, and later in small blast furnaces, but is now made, almost entirely, in the electric furnace. The Wilson Aluminium Co. employ 4,000 E.H.P., and turn out 200 to 250 tons per month of ferro-chrome having 5 to 6 per cent. carbon and over 70 per cent. chromium.

The following are typical analyses of some of the ferro alloys :—

	Ferro-manganese. Blast furnace.	Spiegel-eisen. Blast furnace.	Ferro-silicon. Blast furnace.	Ferro-silicon. Electric furnace.	Silicon spiegel. Blast furnace.
Manganese	80	20	.3	?	19
Iron	12	73	83	?	66
Carbon	6.8	5.0	1.7	Trace	1.7
Silicon	1.0	1.1	14.8	50	13
Sulphur	.02	.02	.08	Trace	.08
Phosphorus	.10	.10	.12	.02	.10
Arsenic	.10	....	....	....	....

	Crucible furnace.		Ferro-chrome. Electric furnace.	
Chromium	45	60	72.7	68.2
Iron	45	30	21.4	29.9
Carbon	8.6	9.1	5.3	1.3
Silicon	.6	.5	.6	.11
Manganese	.4	.3	....	....
Sulphur	.05	.05	....	.01
Phosphorus	.05	.05	....	.01

In dealing with these and other products of the electric furnace, it should be remembered that they will sometimes evolve explosive gases if allowed to come in contact with water. This may be due in some cases to small quantities of calcium carbide formed at the high temperature of the electric furnace, but in one case, that of some ferro-silicon, which produced a number of explosions in Liverpool a few years ago,** the explosive gas was found to be phosphoretted hydrogen. The alloy was very pure, containing nearly 60 per cent. of silicon, with 2.7 per cent. of aluminium, .2 per cent. of carbon, .14 per cent. of calcium, .17 per cent. of magnesium, and .56 per cent. of phosphorus.

Manganese, nickel, chromium, tungsten and other metals can also be obtained in a carbon-free and nearly pure state, suitable for use in the manufacture of special varieties of steel by the Goldschmidt process of mixing the oxide of the metal with powdered aluminium and igniting the charge by means of a small primer, which starts the reaction between the oxide and the aluminium. The reaction once started continues throughout the mass, producing an intense heat, which is sufficient to melt the reduced metal and the resulting alumina.

Calcium Carbide.—This important product of the electric furnace has already been referred to, p. 172, and the Willson carbide furnace was illustrated in Fig. 7.

The equation, $CaO + 3C = CaC_2 + CO$, representing the formation of the carbide, shows that 56 parts of CaO, usually as lime, combine with 36 parts of carbon, coke being usually employed, to form 64 parts of calcium carbide. The lime and coke, which should not be too finely powdered, as this would cause loss by dusting, are mixed together and heated in the electric furnace to a temperature which is supposed to be 2,000° C. or 3,600° F. The carbide is molten at this temperature, and may be allowed to build up a block of carbide, which gradually solidifies as the zone of fusion

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‡ Steinhart, Trans. Inst. Min. and Met., Vol. XV., 1906, p. 228.

**A. Dupré and M. B. Lloyd, Journ. Iron and Steel Inst., 1904, Vol. I.

is raised in the furnace, or the carbide may be retained in a fully molten state until there is enough to tap into a mould. The Willson furnace is of the former type. The production of one long ton of a commercial product containing 80 per cent. of pure carbide requires the expenditure of about 4,000 kilowatt hours of electrical energy.

Aluminium.—This is the most important metal that is produced solely in the electric furnace. Originally it was obtained by complicated chemical methods involving the use of metallic sodium as a reducing agent, but the electrical method, described on page 171, entirely supplanted the older processes. The common metals—iron, copper, lead, tin, zinc, etc.—occur in their ores as oxides, or can easily be converted into oxides by a roasting operation, and these oxides are easily reduced to the metallic state by the action of carbon in an ordinary furnace, because, at such temperatures, oxygen has a greater affinity for carbon than it has for the metal, so that carbon is able to combine with the oxygen contained in the oxide and leave the metal free. Other metals, however, such as aluminium, calcium, silicon, sodium, and others have a greater affinity for oxygen than those already mentioned, and it is very difficult, and in some cases impossible, to reduce the oxides of these metals by means of carbon at ordinary furnace temperatures. With the aid of electricity, however, any metal can be reduced, in some cases by heating the oxide to a very high temperature, at which the affinity between the metal and oxygen is lessened, so that the latter can be removed by means of carbon, or by dissolving the oxide or other ore of the metal in a suitable solvent, and applying a direct electric tension to tear, by electrolysis, the compound into two parts, thus liberating the metal. Aluminium, calcium, and other metals can be reduced by carbon at the high temperature of the electric furnace, but immediately combine with a further quantity of carbon, forming a carbide. It is, therefore, necessary, when the pure metal is desired, to employ electrolysis instead of direct reduction with carbon. As examples of the electrolytic reduction of metals at furnace
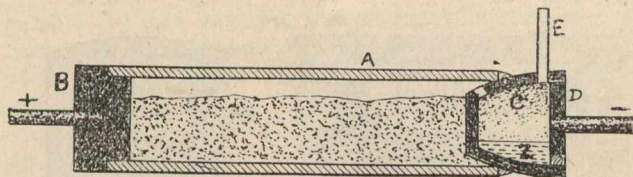

Fig. 30.—Cowles' Electric Zinc Furnace.

temperatures, may be mentioned the production of aluminium already described, and of sodium, which will be described later.

Zinc.—Although one of the common metals, and one that has long been produced in furnaces fired by coal or gas, the volatility of zinc and the ease with which it becomes oxidized present serious difficulties in the treatment of its ores, and many attempts have been made to overcome these difficulties by smelting zinc in the electric furnace.

In the usual process of zinc smelting, the ores are first roasted to remove the sulphur in the case of sulphide ores, or the carbonic acid in the case of carbonate ores, and the resulting oxide of zinc is mixed with about one-half its weight of coal and heated in retorts or muffles made of fire-clay. In order to complete the reduction of the oxide to the metallic state it must be heated to a temperature above the boiling point of the zinc, which is consequently given off as vapour, and passes in that form out of the retort, and is condensed to the liquid metal in a condenser, from which it can be removed and poured into moulds.

The residue is then removed from the retort and the operation repeated. The retorts are heated externally by coal or gas firing, and as the ore must be heated to about 1,200° C. or 2,200° F., the retorts cannot usually be made very large, and frequently only hold about 100 pounds of ore mixture, from which it will be seen that the cost of labor in zinc smelting is likely to be high. The utilization of heat in these furnaces is also very poor on account of its slow transmission through the walls of the retorts, the heat