THE GARUTI PROCESS OF GENERATING OXYGEN AND HYDROGEN.*

By EMILE GUARINI.

For more than a century scientists have endeavored to apply oxygen and hydrogen to various industrial uses. But the difficulty of generating the gases in an economical way has to a large extent prevented the realization of this idea.

No doubt the most familiar method of generating the two gases simultaneously consists in electrolytically decomposing water. But theoretically the decomposition of water by the electric current, which seems fully to answer all requirements, is, nevertheless, of no commercial value. The experimental apparatus is simple enough; but the difficulties encountered in a commercial installation are almost insuperable. Two essential conditions must be realized; the one, reduction to a minimum of the electromotive force, the other, perfect separation of the two gases.

In order to realize the first condition, it is necessary

tural difficulties, and cost of maintenance prevented a commercial realization of their ideas.

An Italian physician, Dr. Pompeo Garuti, conceived the idea of using a metallic diaphragm, which *a priori* seemed to be impossible of success. If a plate of metal be placed between two electrodes, it will be electrolyzed by influence, the positive electricity flowing over the face opposite the negative electrodes and negative electricity flowing over the face opposite the positive electrode. The metallic diaphragm is nothing more or less than a bipolar electrode; consequently, in each compartment, there must be produced simultaneously hydrogen and oxygen, that is to say, an explosive mixture.

Garuti has proven that this phenomenon will not be produced if the electromotive force of the current does not exceed three volts and if the intensity is not more than two amperes per square decimeter of the electrodes.

The small resistance of the diaphragm renders it possible to carry out the process of electrolysis with a difference of potential less than three volts.

The rest of the problem is simply to provide a

cells are placed side by side and are open below and partially open above. The left half of each cell inclosing an anode is open; and the right half of each cathode cell is also open. A bell, covering the left half, collects the oxygen; another bell, applied to the right half, receives the hydrogen. When the apparatus is large the diaphragms and the electrodes are held rigidly in place by means of wooden cones placed at the lower part.

Apart from the wearing away of the anodes, which must be renewed at the end of three years, the Garuti apparatus suffers no change by usage. The cost of maintenance is, therefore, very small. The only care that the cells require is filling each day. The concentration of the soda solution should be 25 per cent. A very dense solution facilitates the generation of gas and obviates the passage of the bubbles through the perforations of the diaphragm. Furthermore the greater the density, the greater will be the velocity of ascension of the gas.

For the sake of safety the gas should be frequently analyzed. Analysis can easily be made by means of the Hemple apparatus, or the Bassani electric densimeter based upon Graham's law of the flow of gases, or with Winssinger's densimeter, which is an aerostatic balance.

One coulomb of current will free 0.0829 milligramme of oxygen and 0.703 milligramme of hydrogen, or 0.058 cubic centimeter of oxygen and 0.116 cubic centimeter of hydrogen at a temperature of 0 deg. Centigrade and a pressure of 760 millimeters. Under the same conditions, in one ampere hour there will be released 208.8 cubic centimeters of oxygen and 417.6 cubic centimeters of hydrogen. Since the temperatures are as a general rule 18 to 20 degrees Centigrade, it can be said that an ampere hour will free 0.4 liter of oxygen and 0.2 liter of hydrogen.

In order to ascertain the theoretical electromotive force required, Thompson's rule can be employed, according to which rule, the heat generated by the formation of water is equivalent to the electric work necessary for decomposition. One gramme of water

A GARUTI INSTALLATION FOR THE ELECTROLYTIC PRODUCTION OF OXYGEN AND HYDROGEN.

TYPES OF BLOWPIPES.

DIAGRAMS ILLUSTRATING THE GARUTI ELECTROLYTIC APPARATUS.

VARIOUS FORMS OF OXY-HYDROGEN BLOWPIPES.

to determine exactly the most suitable composition of the electrolyte, that is, the liquid to be decomposed. Furthermore, the same device must be used by which the two electrodes can be adjusted toward and from each other. In order to fulfill this second condition, it is necessary to place a diaphragm between the electrodes. The circulation of the electrolyte being necessary to insure continuity of operation, the diaphragm should be permeable to the liquid. But in order to insure the separation of the gases, the diaphragm must be impermeable to them. Consequently, it becomes necessary to devise a diaphragm permeable to liquids, but impermeable to gases, and a good conductor of electricity. Diaphragms of every possible substance have been used; all in vain. Renard, Latchinov, Schuckert, Schmidt, and Flament used diaphragms of porcelain, pipe-clay, carbon, and the like. But the great electrical resistance, the impossibility of preventing the gases from mixing with the liquid, struc-

means for the sure circulation of the electrolyte. The better the circulation, the less will be the resistance. The position which gave the least resistance was found to be that in which the lower extremity of the diaphragm did not descend below the electrodes. But the gases mixed. In order to avoid such a mixture the diaphragm must be lowered, which in turn entailed an increase of resistance.

The difficulty thus presented has been avoided by perforating the metallic diaphragms. These perforations have a diameter of one millimeter. They allow the electrolyte to pass through, and are but slightly permeable to the gases.

The problem of providing a suitable diaphragm having been solved, the inventor now sought to devise a suitable cell. After many experiments a cell was adopted which consists of a series of smaller cells inclosing each an electrode, and composed of sheets of soft steel soldered together so that the joints would be all liquid-tight. The electrolyte consists of a solution of caustic soda or potash. The

SOLDERING WITH OXY-HYDROGEN BLOWPIPE.

releases about 3.8 calories or $3.8 \times 425 = 1,615$ kilogrammes. One coulomb will decompose 0.0000933 gramme of water. To decompose one gramme of water, work must be performed equivalent to

$$\frac{1}{0.0000933} = C \times x \text{ volts;}$$

or in kilogrammes

$$\frac{1 \times}{0.0000933 \times 9.81}$$

Hence we may write

$$\frac{x}{0.0000933 \times 9.81} = 1615$$

from which it follows $x = 1,615 \times 0.0000933 \times 9.81 = 1,488$; or in round numbers 1.5.

Theoretically, the electromotive force may therefore be considered 1.5 volts. Practically, this figure cannot, of course, be realized. From a calculation made by M. Eric Gérard, a Garuti electrolyzing apparatus constructed of sheet steel and containing the best caustic potash required an electromotive force of 1.988.

In actual industrial practice it would not be possible to reach so high a figure with a lower grade electrolyte, which costs somewhat less, but offers somewhat more resistance. The average electromotive force obtained under these conditions with such an electrolyte would be 2.4.

With this maximum voltage, and allowing for a production of 0.4 liter of hydrogen and 0.2 liter of oxygen per ampere hour, the production per kilowatt hour would be 166.6 liter of hydrogen and 83.3 liters of oxygen, or in all 290 liters of oxyhydrogen gas. The production of 1 cubic meter (35.315 cubic feet) of this gas (666 H and 333 O) therefore requires 4 kilowatts. A cubic meter of hydrogen requires 6.25 kilowatts, and 1 cubic meter of oxygen 12.5 kilowatts.

A company has been formed not only for the purpose of exploiting the Garuti process, but also for manufacturing special implements for the utilization of oxyhydrogen gas.

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