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LOW-OUTPUT INSTALLATIONS FOR OBTAINING OXYGEN AND HYDROGEN BY ELECTROLYSIS

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L. M. Yakimenko, Engineer

(Note: Leonid Markovich Yakimenko is vice-chief engineer of the Chirchik Chemical Combine, in the construction of which he took an active part. He is a specialist in the construction and use of plants for obtaining oxygen and hydrogen by electrolysis, and is one of the designers of the electrolytic plants in use in the USSR.)

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The electrical method of obtaining hydrogen and oxygen finds application in factories making synthetic ammonia, where electrolytic installations of large output operate. However, oxygen and hydrogen are needed also by numerous small consumers. Among this number belong: factories making transparent quartz and artificial stones; hydrogenation plants; factories making electrical lamps and tubes, rare elements, hard alloys; enterprises with special missions; and, finally, machine-construction factories.

The consumption of gas for most users of these gases is usually from 10 to 50 cubic meters per hour (m^3/hr). In this case most consumers require gases under a pressure of 12 to 15 atmospheres.

Box-type electrolysers, which are widely employed in foreign countries, possess many defects and, therefore, are impossible to recommend for introduction into our industry.

To create compact, convenient-to-use installations for producing electrolytic oxygen and hydrogen under pressure, one needs, besides design work, apparatus to be used in important critical tests of experimental samples. In the making of an apparatus for electrolyzing water under pressure, the greatest difficulties have been: a) the working out of a design for an electrolyzer which would definitely guarantee, for a sufficiently simple design, the necessary hermetical gas-tight construction of the apparatus; and b) the creation of a system for regulating the pressure of both gases which would ensure, even for maximum fluctuations of pressure in the gas-separating 'network system' ('mesh' or 'circuit'), a difference in pressure of both gases in the same electrolyzer not higher than 100

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to 200 mm in the water column. For a pressure of 15 atmospheres, the difference in pressure of both gases must not exceed 0.1% of the total pressure.

These difficulties were overcome by using an electrolyzer design proposed by this author and A. I. Koleskov (Certificate of Authorship No. 54309), and also by employing an arrangement for maintaining a pressure difference in the gases in the electrode spaces of the electrolyzer, as proposed by a group of engineers (L. S. Genin, A. I. Koleskov, V. M. Ramm, N. M. Solomatin, V. G. Khomyakov, and L. M. Yakimenko—Certificate of Authorship No. 51206).

The schematic diagram of the installation for electrolyzing water is shown in Figure 1. The apparatus consists of: an electrolyzer 1, in which the decomposition of water takes place into hydrogen and oxygen; two separating ('fractionating') columns 2, which serve for the purpose of roughly separating the liquid from the gases and for cooling the electrolyte circulating from the electrolyzer to the separating columns; a filter 3, placed in the path of circulation of the liquid for removing coarse suspended particles in the electrolyte; and a system for regulating the pressure of gases and supplying the feed water to the electrolyzer.

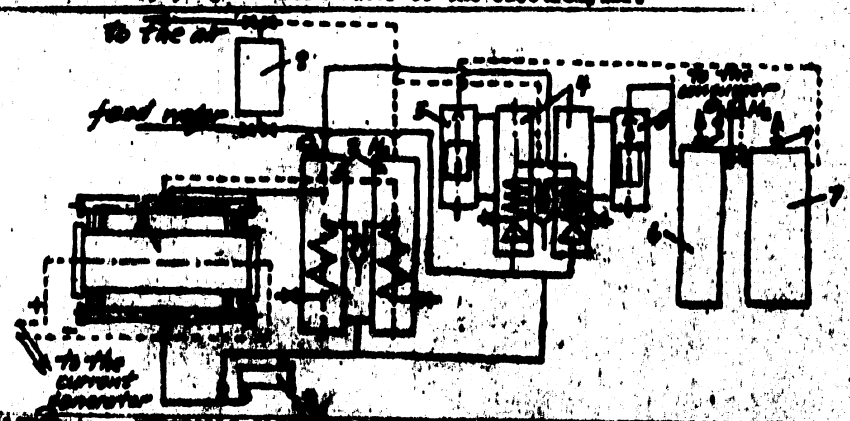

Figure 1. Schematic diagram showing the industrial installation for electrolyzing water. (1) electrolyzer; (2) separator columns; (3) filter; (4) scrubbers for cleaning the gases; (5) pressure equalizers; (6) receivers; (7) receivers; (8) head (contents under pressure); (9) safety valves.

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The apparatus for regulating the gas pressure consists of: two scrubbers of the bubbler type, which serve at the same time to cool and wash the gases clean of the spray from the electrolyte; and two pressure equalizers 5 of the floating type.

Receivers 6 and 7 serve to hold the gases and to dampen their pressure fluctuations in the case of irregular gas-consumption. Forced delivery or head, 8 is maintained in order to supply feed water to the system without the use of high-pressure pumps.

The electrolyzer (Figure 2) is a filter-press apparatus consisting of 50 or 97-100—depending upon the pressure of flow necessary for feeding—series-connected cells, or compartments, which are compressed between two steel plates 1 by four bolts 4 and 5.

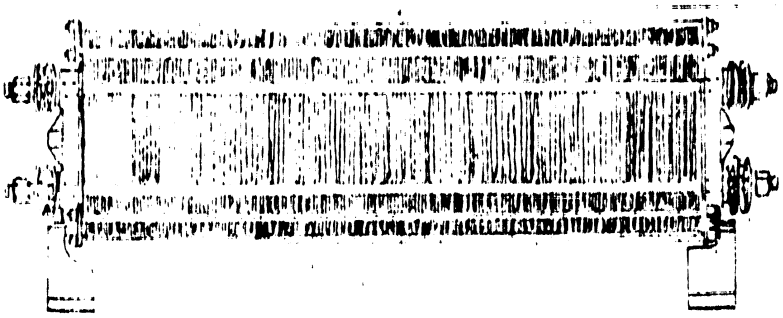

Figure 2. Filter-press electrolyzer. 1,2,3) terminal plates; 4,5) bolts; 6,7) insulated bushing; 8) gaseous channels; 9) feed channel.

In order to compensate for temperature expansion and contraction, bolt packing (gasket) is provided by a complex of plate-like spring disks.

Each cell-like compartment of the electrolyzer (Figure 3) consists of: two operating bipolar electrodes ~~electrodes~~, provided in order to decrease the tension by the 'support' electrodes 2, between which is compressed a diaphragm frame 4 made of section-shaped metal, which (frame) supports the diaphragm 5 made of asbestos fabric. Each electrode operating in one cell as a cathode serves as an anode in the neighboring cell. The mixing of the gases that are evolved during the flow of current—namely, hydrogen at

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the cathode and oxygen at the anode—is prevented by a diaphragm which diverts separately the gases from the electrode spaces.

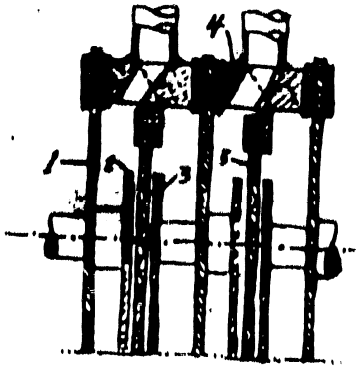

Figure 3. A cell of the electrolyzer. 1) bipolarly-operating electrode; 2,3) 'support' electrodes; 4) diaphragm frame; 5) diaphragm of asbestos fabric;

In order to collect the gases, the electrolyzer is provided above with two gas-collecting channels. These channels are made up completely of as many sections as there are cells of the electrolyzer. Each cell has its own sections of the gas channels, which (sections) are united with the frame of a cell by tubes that draw off the gas.

Below, the electrolyzer is made like a so-called feed channel, which serves to conduct into the cells water and circulating electrolyte.

Packing and electrical insulation of the electrodes from the diaphragm frames, and also from the sections of the channels, are effected by means of 'paranite' gasket layers.

The entire electrolyzer rests, by means of terminal plates, upon a foundation and is insulated by insulating layers from the ground.

In order to draw off the excess heat given off during electrolysis, to equalize the concentration of alkali in the cathode and anode spaces, and to simplify the elimination of the gases formed, constant circulation of the electrolyte is carried on throughout the electrolyzer.

The electrolyte, together with the gases in the form of a gas-liquid

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emulsion, comes out of the cells into the gas-collecting channels of the electrolyzer and from there to the separating columns for hydrogen and oxygen. In the columns are carried out a rough separation of the gas and liquid. After that the gases arrive at the washers and equalizers, and the electrolyte from both columns, after cooling, is stirred and passed through the filter and the feed channel and is again fed back into the cells of the electrolyzers.

The driving forces that ensure the constant operation of the circulating system are the differences in specific weights of the gas-liquid mixture in the electrolyzer and in the electrolyte in the channels, and also the ejecting effect possessed by the gaseous currents from the cells of the electrolyzer into the collecting channels.

The pressures of both gases are regulated by the scrubbers and equalizers which combine a scheme of hydraulic pressure with a floating regulator of the valve type. Final fine regulation is ensured by the hydraulic part of the installation.

The gases arriving under the bubbles, after being washed clean of alkali spray and cooled, are directed to the pressure equalizers, and from there they go to the receivers.

When a difference in gas pressure in the consumption ('output' or 'use') network and in the receivers is produced, the levels of the liquid in the scrubbers and equalizers change.

In the equalizer of the gas having a low pressure, the level of the liquid rises and the channel joined to the float shuts off the output of gas until equality in the pressure of the gases is established and there is a normal distribution of liquid levels in the apparatus. A certain difference in gas pressures that arises here in the equalizers is finally compensated by a different height of the gas bubbler in the scrubbers and in the electrode spaces. The difference in pressure of the gases, in practice, does not exceed 100 to 200 mm in the water column for minimum fluctuations in pressure in the external network.

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The [illegible] in Figure 1 provides for the operation of the electrolyzer under maximum pressure which is limited with the aid of the safety channels [illegible] on the receivers. When the consumption of both gases is not uniform, the surplus gas will be ejected into the atmosphere through a safety channel of a receiver. This scheme is used mainly when both gases are [illegible]. When the capacity of the receivers is chosen accurately, the ejection of the gases into the atmosphere can in practice be eliminated even when the consumption is irregular in respect to time.

When mainly using only one gas, another scheme is employed. In this scheme, the gaseous contents of the equalizers are joined directly to the gas receivers, and the valves operate the ejection of surplus gas into the atmosphere.

The level of the liquid in the electrolyzer is fixed by an indicator on the bubblers of the gas scrubbers, without dependence upon the level of the liquid in the same scrubbers. In this situation, it is essential and necessary that the variation in specific gravity of the liquid in the electrolyzer under influence of gas inflation and high temperature be taken into account, also the difference in concentrations of the alkali in the electrolyzer and in the gas scrubbers.

On this is [illegible] the automatic feeding of the electrolyzer with water through the scrubbers, which (scrubbers) serve at the same time also as a liquid buffer.

In view of the fact that the equalizers of pressure tolerate large fluctuations when they are full of liquid, it is necessary to add feed water to the scrubbers from 2-3 hours.

In order not to use high-pressure pumps for supplying feed water, a pressure tank is [illegible], the pressure in this tank is created by connecting it to one of the gas [illegible]. Such a scheme is conducted with the consumption of a small quantity of one of the gases; however, this consumption is completely [illegible] because of the elimination of the feed pumps.

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The electrolytic apparatus for obtaining hydrogen and oxygen have different productivity, or yield. The main indices governing small installations are shown in the Table.

Table

The Main Indices of Small Installations for Obtaining Hydrogen and Oxygen by Electrolysis.

Type of Installation	Rated Load	Voltage	Yield m^3/hr H^2	Yield m^3/hr O^2	Max. press.	No. of cells
FK-12	600	230 v.	24	12	12 atm	100
FK-12/115	600	115	12	6	12	50
FK-6	300	230	12	6	15	100
FK-6/115	300	115	6	3	15	50
F-97-50-1	1200	230	46	24	1	97

All types of electrolyzers permit prolonged overloads up to 35% with a corresponding increase in yield.

The electrolyte used is a 28-30% solution of potassium hydroxide or 20-22% solution of NaOH.

The consumption of electrical energy per cubic meter of oxygen and 2 cubic meters of hydrogen depends upon the load, operating temperature of the electrolyzer, and the electrolyte used. When operating with a temperature of 70°C with a normal load and an electrolyte of KOH, the voltage in the cells is 2.23 to 2.25 volts, which corresponds to a consumption of 10.8 to 11.0 kilowatt-hours (kw-hr) of direct current per cubic meter of oxygen and $2m^3$ of hydrogen under normal conditions.

The consumption of feed water, taking into account all losses, is 1.8 liters per cubic meter of oxygen and $2m^3$ of hydrogen. It is desirable to use condensate that is free of suspended iron as the feed water. One can use ordinary piped water instead of condensed water when a small amount of liquid is needed.

The consumption of piped water for cooling the electrolyzer and the gases produced by it fluctuates, in dependence upon the load on the apparatus,

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temperature, and initial temperature of the water, from 60 to 200 liters per cubic meter of oxygen and $2m^3$ of hydrogen.

Electrolysers can be fed from mercury rectifiers of 230 volts or from motor-generators of 230 or 115 volts.

When a current source higher than these (up to 500 volts) is available, one can connect the electrolysers in series with the direct-current circuit. In this case it is necessary to ensure that the apparatus is insulated from the ground.

The use of voltages higher than 500 volts for small installations is not recommended because of the necessity for employing a number of safety measures and complications in the servicing of the installations.

The production of apparatus for obtaining electrolytic oxygen and hydrogen under pressure up to 15 atmospheres, designed for outfitting small and medium establishments, has been completely mastered in the Soviet Union. Electrolytic installations are compact, dependable in operation, and simple to service. There is a possibility of manufacturing mobile installations.

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