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HYDROGEN & FUEL CELLS

INDUSTRIALIZATION OF ELECTROCHEMICAL PROCESSES

Voltiana® Cells and Systems

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CASALE CHEMICALS

INDUSTRIALIZATION
OF
ELECTROCHEMICAL PROCESSES

Voltiana® Cells and Systems

One usually defines any type of apparatus in which chemical reactions occur as a *chemical reactor*. To extend this concept, when these reactions transform electrical energy into chemical energy or vice-versa, we can say that we are in the presence of an *electrochemical reactor*, a terms that describes apparatuses more commonly known as *electrolytic cells, electrochemical cells, electrolysers, batteries,* etc.

With so many names available, why should one create a new one? Since the word "*reactor"* has well defined implications with disciplines in chemical engineering, we, as chemical engineers, are convinced that the design of *electrochemical reactors* is an action that falls within the scope of our field of activities.

In fact, an *electrochemical reactor* involves aspects of chemical kinetics, material and heat transfer, fluid dynamics and material science, which are all chemical engineering arguments. In order to extend these concepts, we can recognise *electrochemical reactors* of *discontinuous* type, as for example, the batteries during the charge and discharge phase, or *continuous* reactors, such as water or alkali chlorides electrolysers, electro-dialysers, and fuel cells.

Having noted that each unit belonging to the process plant influences all of the others, sometimes in a very obvious way and other times in a quite subtle manner, our intervention brings about an analysis of the entire system that revolves around the reactor, including the equipment used to feed the reactants, to remove or supply heat, to separate, purify the products, i.e. *unit operations* well known in the field of chemical engineering.

This explains our approach to electrochemical plants, with a contribution that, outside the reactor, takes the entire system into consideration, including for instance, the equipment and control criteria. Within the reactor, on the other hand, we must guarantee functionality, efficiency, reliability of the components and of the materials, which are obtained through rational design and engineering, that respects the dynamics of fluids, the distribution of the electrical potentials and currents, the material and heat transfer, the corrosive phenomena, the operating pressures and temperatures.

From the work carried out within the internals of *electrochemical reactors*, we have developed our modular systems of electrochemical cells registered under the brand name VOLTIANA®, in honour of the scientist who, two hundred years ago, gave a practical push to start electrochemical disciplines and relevant experimentation.

VOLTIANA® cells, patented in most industrialised countries, are the result of an innovative engineering study, the outcome of an analysis of the state of the art extended to various types of commercial electrochemical cells that, for historical reasons, did not reap the fruits of the technical evolution, as happened for instance, in the petrochemical field. Our study of the existing markets, on the other hand, has driven us to carefully re-examine the electrochemical processes and the most modern means to actuate them.

VOLTIANA® cells are modular, starting from standard-sized elements. Generally they are recognised as *electrochemical reactors* with flat electrodes, assembled in a typical *filter-press* configuration. Fundamental elements are the modular cells, or *frames*, that make up the structure containing the parts that directly interest the electrochemical process, such as the electrodes, diaphragms, etc., and of course, some electrolytes and reaction products. These *structural frames*, one of which is shown in **Fig. 1**, are produced through injection-moulding of *composites*, based on a polymer matrix reinforced with fibres and other materials. It involves materials of very high mechanical characteristics, which may replace metals in many applications.
Fig. 2 shows five different sizes of *structural frames* produced until today. They can support flat electrodes with surfaces of, respectively, 25, 100, 500 cm^2, 0.25 and 0,5 m^2, covering the entire size range from laboratory scale to pilot or industrial plants.
Each frame acquires a specific purpose in connection with the components installed in it (electrodes, diaphragms, membranes, bipolar plates, etc.) through a special fixing procedure; each frame contains all of the necessary channels (formed during the moulding process) to convey and collect the process fluids.

Fig. 3 shows, next to a structural frame, some of the internal components, typically thin and flexible, that adhere one to the other in the space of a few millimetres. The coherent assembly of these frames and relevant internal parts takes place in a preordained sequence and results in a cylinder resistant to pressure (until now up to the operating limit of 30 bar) in which all the components necessary to carry out the electrochemical reaction are present. This horizontal battery, kept together by two terminal heads connected by bolts, which reminds one of a *filter-press*, is often indicated in the field with the name *stack.* Given the thinness of the components and the structural frames, one can easily build a *stack* that, in very little space, contains hundreds of elements.

The field of materials utilisable to mould the structural frames is so vast, that one can always find a solution to guarantee the resistance to chemical attack of each possible electrolyte. The electrical non-conductivity of the structure has many advantages, such as the elimination of the flat insulating seals (gaskets) between consecutive metallic frames, the process fluid conveyed by means of internal channels, the electrical and thermal insulation and operating risks to the operators.
The reduced cost, the speed and the simplicity of production with respect to any metal frame, must be kept in mind.

With the proper choice of assembly, *stacks* adapted to various electrochemical processes, from electrolysis with or without diaphragm, with membrane, with compartmental cells, with solid polymeric electrolytes (SPE), with the use of a membrane-electrode assembly (MEA) or systems based on gas diffusion electrodes (GDE), satisfy the various fields of application of the *electrochemical reactors*, from electrolysers to electrodialysers, flow batteries, to fuel cells.

To this one must add the simple scaling-up of the reactor, due to its peculiar configuration, in which the thickness and nature of the internal components remain constant even when the electrode surface is changed. Our industrial development work starts in the electrochemical laboratory, where the reactions are carried out using electrodes with a surface of a few square millimetres and mini-reactors usually made out of a basin working in discontinuous mode.

As a first step, we suggest to repeat the experiments in small reactors, made with single cells or by a *mini-stack* that we have adopted due to its scalability, to figure out how much shall be produced on an industrial scale. By completing everything with the proper dosing systems, the operation becomes continuous, with material flowing in appreciable quantities, in closed or sometimes pressurised reactors.

Fig. 4 shows a laboratory *mini-stack*, assembled with twenty cells of the smallest size. It can be used with continuous electrical current up to 10-12 A and at a power transfer of a few Watts.

Instead, **Fig. 5** shows an industrial *stack* made up of 125 bipolar cells, built for the electrolysis of water, capable of producing up to 50 Nm3/h of hydrogen (and naturally 25 Nm^3/h of oxygen) operating at a current of 1000 A.

Fig. 6 makes up the major stack produced up to now by our Company, designed to generate 100 Nm^3/h of hydrogen, operating at a pressure of 6 bar at a current of 2000 A. The involved power is 500 kW.

Fig. 7 shows a typical pilot plant, with an installed output of 5 kW, operating at a pressure of 30 bar, with the possibility of using a remote control system managed by a PC.

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VOLTIANA® cells and electrochemical systems have been supplied to many Research and Development groups throughout the entire world. Our Company is available to cooperate with Clients' R&D sectors to develop new processes based on electrochemical reactors, furnishing the necessary pilot, demonstration and industrial production units.

Our experience is certainly useful under all the aspects of chemical engineering involved in the realization of industrial processes.

We shall, therefore, be pleased to assist in the design, engineering or production of reactors and electrochemical processes on various scales that researchers care to bring to our attention.

Lugano, 15th March, 2000

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