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# Giuseppe Eugenio Balsamo's Iron-Lead Pile, Giuseppe Candido's Regulating Diaphragm Pile: Two Contributions from Lecce to the Development of Volta's Battery

During the course of research carried out over the last few years to uncover the scientific heritage of Salento, the contributions of some local scholars to the development of the applications of electricity have been brought to light.

Amongst the most interesting of these contributions are undoubtedly those studies carried out by G.E. Balsamo on the behaviour of iron and lead in a voltaic cell, and the invention of a regulating diaphragm pile by G. Candido, a priest from Lecce. The latter created a network of synchronous public electric clocks between 1868 and 1874.

With his regulating diaphragm pile, obtained by combining Callaud's pile and Minotto's sand pile, both modifications of Daniell's pile, Candido created a device able to emit a constant current for long periods of time, both cheaply and with easy maintainance. This was precisely what was needed to make electric clocks and telegraphs work. Patented in 1867, the regulating diaphragm pile earned its inventor public recognition the same year at the International Exhibition in Paris.

Balsamo, a lawyer born in Lecce too, had many scientific interests, and was for many years concerned with the economy of production of electrical energy using voltaic cells. He wanted to reduce the costs through the use of cheap materials and the production of useful by-products. Thus he devised a pile in which the iron could constitute both the electrodes at the same time and a particular combination of the lead pile, in which ceruse (white lead) – widely used in the dye industry – could be obtained as a by-product. The results of these studies are to be found in a paper read to the Academy of Science in Paris on September 23, 1867.

Lecce is a town with a notable artistic and historic past. It is famous for its baroque architectural style, which flourished in the period of complete urban renewal of the town in the 16th and 17th centuries. These architectural characteristics and the well-known figures of artists and men of letters have had the effect of pushing the majority of the cultural aspects tied to the development of the natural sciences into the shade. With the term "natural sciences" we broadly include both physics and chemistry.

What is more, many of the foremost figures of culture in Lecce had carried out medical studies, and until the end of the last century these were strictly tied to those of physics, chemistry and biology. Hence these people ended up being brilliant in fields that were very different from those to which they were professionally bound, not excluding of course literary or artistic ones. This underlines the fact that culture had kept its basic unity until at least the end of last century, though it has unfortunately gradually lost it in the course of the following century.

It is precisely to restore to light and public knowledge all this scientific heritage, largely hidden or forgotten, when not completely lost, that for many years we have been undertaking systematic research, which has produced quite a lot of surprises. Certainly amongst the most interesting ones are the large number of pieces of apparatus for the teaching of physics found in the town schools[1] and the discovery that Lecce, although a town on the periphery, with regard to the areas in which technological progress was taking place during last century, deserves a noteworthy position in the history of the applications of electricity.

Between 1868 and 1874 it in fact saw the creation of the first Italian network of public electric clocks synchronized electrically. This was subsequently also found to be one of the first and most efficient ones in Europe. In 1898 the town also had the longest electric tramway in Italy.[2] If to this we add that in 1858 and 1859 Lecce had two of the first public demonstrations of the use of electric lighting, it is easy to see that the town deserves such a place in the history of electricity.

There are two really important figures in the development of the applications of electricity in Lecce: Giuseppe Candido and Giuseppe Eugenio Balsamo.

Giuseppe Candido[3] was a priest with a degree in mathematics and physics from the University of Naples. He had been a student at the College of San Giuseppe run by Jesuits, where he had had Father Nicola Miozzi as his physics teacher. The latter was a great authority on electricity and in his turn had been a pupil of Father Giuseppe Maria Paladini, a great friend of Macedonio Melloni and an expert on Ampère's theories of electromagnetism.

Miozzi had carried out various experiments on the use of electricity in Lecce and in 1859 had given one of the first public demonstrations of the production of electric light, illuminating the Palazzo dell'Intendenza with an arc lamp fed by a battery of Bunsen piles on the occasion of the visit of King Ferdinand II to the city.

Candido devised various electrical apparatuses of practical use, but his most important one consists of a network of four large public clocks, controlled synchronically by electricity from a clock motor with a mechanical pendulum. The latter controlled the four ringing mechanisms electrically too. He also devised and

[1] See ROSSI, RUGGIERO, BERNARDINI (1991).
[2] See RUGGIERO (1998).
[3] Born in Lecce in 1836, he died in 1906 on Ischia (Naples), where he had been sent to govern the diocese after his promotion to the bishopric desired by Pope Leo XIII.

built an electromagnetic pendulum which beating seconds, which was to substitute the mechanical pendulum in the network of public clocks, and a system of thermoelectric cells which could regulate the clock motor on the passing of the sun across the meridian of Lecce.

For all his electrical apparatus, but above all for the powering of the clocks, Candido invented a new electric battery, called by him, the regulating diaphragm pile, which allowed a constant current to be produced for long periods at low working cost and was very easy to maintain. These were the characteristics needed for the batteries that, in that period, were to power above all the telegraph networks, as well as the public clocks whose technology was not yet in a very advanced state.

Candido derived his pile from the fusion of two of those then widely used in telegraphic networks, Callaud's pile and Minotto's pile, both devised to overcome the problems which made Daniell's pile not very reliable.

The principle on which they worked was that of Daniell's pile, but in both the porous vase had been eliminated. The function of this vase was to keep the two liquids separate, but in fact it was the main cause of the defective functioning of the battery itself.

In his pile[4] the Frenchman Callaud[5] had obtained the separation of the two liquids by gravity, exploiting their different densities, thus putting the zinc electrode in the upper part of the container. In his pile[6] the Italian Minotto had inserted between the liquids a layer of sand to increase the separation between them. In both there were crystals of copper sulphate present, whose slow dissolving maintained the concentration of the solution relatively constant.

Candido reintroduced into his pile (figure 1) a ceramic separator, not however porous, which besides separating the two liquids and supporting the zinc ring electrode, kept the sand separate also from the upper solution. Thus it was possible, without causing any remixing of the two liquids, as happened in Minotto's pile, to control the level and quantity of the copper sulphate, and consequently the characteristics of the current, hence the name "regulating diaphragm". A simple visual inspection of the intensity of the colour of the liquid in the lower part of the container allowed one to see the state of the pile and therefore to intervene if necessary (figure 2).

Candido patented his pile in 1867, presenting it then, together with the designs of various electrical apparatuses, to the International Exhibition of Paris of the same year and receiving a complimentary "honourable mention". His pile and other

[4] See GANOT (1876), p. 580.
[5] See CALLAUD (1875).
[6] See GANOT (1876), p. 580.

apparatus presented at the Exhibition were described by Father A. Secchi[7] and by Abbot Moigno.[8]

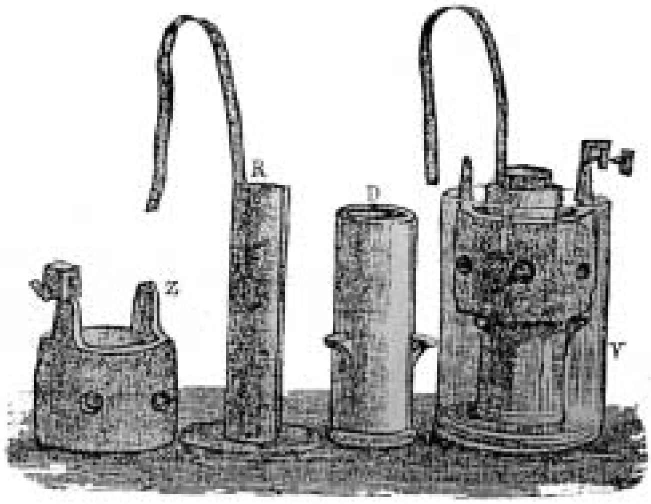


**Figure 1** Candido's pile (from Secchi 1867). V: glass vase, Z: zinc, R: copper, D: non porous ceramic diaphragm.

Candido's pile passed all the tests necessary for its use in telegraph networks, but it was not adopted because another contract for other batteries had already been agreed on.

In the same year in which Candido's regulating diaphragm pile won the honourable mention at the International Exhibition in Paris, E.M. Peligot, the famous French chemist who had discovered many organic compounds, read out Eugenio Balsamo's paper "Nouvelle pile voltaique au fer et nouvelle pile voltaic au plomb" (New voltaic cell using iron and new voltaic cell using lead) at the meeting of the Academy of Science on September 23.

Giuseppe Eugenio Balsamo,[9] who had graduated in civil and canon law at the University of Naples in 1851, had previously attended the famous Collegio San Giuseppe in Lecce. Then he continued his scientific studies from 1859 to 1860 at the Sorbonne and Mining School in Paris, making important connections in the scientific field, in particular with E.M. Peligot.

[7] See SECCHI (1867).
[8] MOIGNO (1867).
[9] Born in Lecce in 1828, we have not yet found the date of his death, which in any case was after 1890.

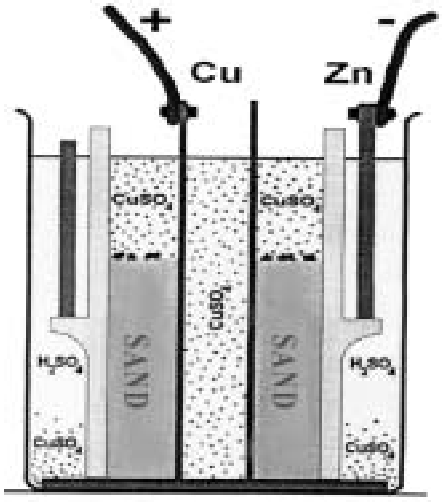


**Figure 2** Diagram of Candido's pile. Above the sand there are some copper sulphate crystals (drawing by M. Di Giulio).

In 1861 he took up the post for the teaching of physics and chemistry at the "G. Palmieri" Royal Lyceum (type of Grammar School), the new name of the Collegio San Giuseppe after the expulsion of Jesuits from Lecce after the creation of a unified Italy.

Balsamo continued his studies in various sectors publishing, also in international journals,[10] works of various kinds, above all on physics and agronomy.[11] He was a member of various Societies and Academies and at a mature age took an interest in economy and politics, thus obtaining election to the Italian Parliament.

In his paper on the new iron and lead batteries, Balsamo included the results of various years' studies in the field of research for new methods of building electric batteries with the aim of keeping production costs low. He followed two paths: that of using low cost materials and that of producing materials that could be used in industrial practice at the same time.

Following the first pathway he studied the possibility of using iron in voltaic elements, whilst on the second path he did various experiments to obtain ceruse (white lead) from a lead pile as a by-product. This was widely used in the dye industry.

[10] *Le moniteur Scientifique*, *Le Technologiste*, *Les Mondes*, *Le Cosmos*, *The Chemical News*, *Das Repertorium der Technik.*

[11] BALSAMO (1860), (1867), (1867a), (1867b).

Studies on the possibility of building iron batteries had been conducted during the first half of the century by various researchers, who had tried to substitute iron for zinc as the oxydizable element. Evidently the results obtained were not encouraging, if Callaud in his treatise on the state of the art of the electric pile[12] does not mention any iron pile and if Figuier, in his famous *L'année scientifique et industrielle*, mentions as a "novelty" the iron pile of the Englishman M. Coleman in 1885[13] and of the Spaniard M.M. Sanchez Navarro in 1888.[14] Both of these were obtained by replacing zinc with iron, in a Daniell pile by Coleman and in a Bunsen one by Sanchez Navarro.

It can thus be seen how Balsamo's research was of particular interest in that it aimed at the realization of a pile in iron in which the iron functioned at the same time as electropositive and electronegative element, exploiting "[...] the properties of iron of polarizing differently in certain situations between which an osmotic action takes place".[15]

| Fer *électro-positif* | Fer *électro-négatif* | FORCE du courant en rapport *avec un élément* Daniell *représenté* par 100 | VARIATION *du courant* en deux jours à circuit *fermé* | OBSERVATIONS |
|---|---|---|---|---|
| Acide oxalique | chlorure de sodium | 83 , 30 (a) | 25 | (a) *trois jours après* |
| Acide oxalique | sulfate de fer | 83 , 30 | » | |
| Chlorhydrate d'ammoniaque | mercure | 94 , 40 (b) | 25 | (b) *trois jours après il se dégageait encore de l'hydrogène du fer au contact du chlorhydrate d'ammoniaque.* |
| Eau aiguisée par l'acide sulfurique | chlorure de sodium | 83 , 30 | » | |
| Eau acidulée d.° | bi-chrômate de potasse | 5 , 50 | » | |
| Eau acidulée d.° | acétate d'ammoniaque | 66 , 60 (c) | 30 | |
| Eau acidulée d.° | chlorate de potasse | 44 , 40 | 30 | (c) *un jour après le fer de l'eau acidulée est devenu électro-négatif et le fer du sel et soufre électro-positif, par l'action des sulfures et chlorures formés dans le vase poreux.* |
| Eau acidulée d.° | soufre mélangé à une solution de chlorure de sodium | 66 , 60 | » | |
| Acide oxalique | mercure | 88 , 80 | 50 | |
| Acide oxalique | mercure chlorure de sodium | 11 , 10 | » | |
| Acide oxalique | sel ammoniac | 70 , — | 19 | |
| Chlorure de sodium | mercure | 88 , 80 (d) | 30 | |
| Chlorate de potasse | bi-chrômate de potasse | 33 , 30 | 20 | |
| Acide azotique étendu | solution de sucre | 82 , 20 | » | |
| Acide azotique étendu | acide oxalique | 87 , 70 | 22 | (d) *Substituant le charbon au fer dans le mercure, le courant est descendu à 10 degrés en quelques minutes.* |
| Sulfate de fer | sesqui-oxyde de fer en suspension dans l'eau | 77 , 70 | 30 | |
| Bi-tartrate de potasse | acétate de fer | 55 , 50 | 40 | |
| Bi-carbonate de soude | chlorhydrate d'ammoniaque | 77 , 70 | 55 | |
| Bi-carbonate de potasse | mercure | 5 , 50 | » | |

**Figure 3** Table of some results obtained by Balsamo with his iron pile (from Balsamo 1867).

[12] GANOT (1876).
[13] FIGUIER (1886), pp. 111-2.
[14] FIGUIER (1889), pp. 103-4.
[15] BALSAMO (1867).

In the course of his experiments Balsamo had observed that iron acquires a certain sensitivity to oxydization if treated in a galvanic bath of phospho-acetate of iron. In fact when a galvanic cell is made using such a compound in which two thin plates of iron of the same "molecular constitution" are immersed, the one connected to the positive pole was attacked by the acid, whereas on the one connected to the negative pole a layer of purer iron was deposited, which should have given it a greater electropositivity. But in fact it was the plate connected to the positive pole which presented an increase of electropositivity. Balsamo attributed this phenomenon to the phosphorous in the solution which, somehow, must have attached itself to the iron of the plate, making it share its great affinity with oxygen, thus raising it on the scale of electropositivity.

In his long paper Balsamo refers to the numerous experiments carried out with pairs of iron plates coming from the above-mentioned galvanic bath, immersed in various solutions of acids and salts separated by a porous partition (figure 3), in the course of which he had discovered that iron possesses a surprising characteristic: unipolarity in liquids; that is to say that it shows that it acquires the same polarity inside and outside the liquid as the voltaic element of which it is part.

As regards the lead pile Balsamo states in his paper that his experiments to obtain colouring substances from the salification of lead had already begun in 1857 and in 1859 he had successfully experimented with 6 couples of a voltaic combination, devised for that purpose, on the underwater telegraphic link of more than 100 kms between Lecce and Valona, in Albania. The paper records next a detailed description of the various experiments carried out using numerous substances and different combinations.

**Figure 4** The battery of Candido's piles that powered the electrical tower-clocks of Lecce from 1868 to 1936, as found in 1990 (picture by L. Ruggiero).

The pile consisted of a glass beaker containing a solution of oxalic acid in which was immersed a lead collar, into which was placed a porous vase containing potassium nitrate dissolved in nitric acid and a carbon electrode; the lead and carbon were provided with copper appendices in order to connect several batteries one to another.

While as regards Candido's pile the proofs of its suitability for use exist in its powering of the electrical clocks in Lecce (figure 4), so far for Balsamo's batteries no documented proofs of their practical use have been found.

An accurate critical analysis of the experiments and processes described by Balsamo needs to be carried out to evaluate precisely their consistency and the scientific importance of the results he reported. Nevertheless there is no doubt that they were of some importance if they had a supporter of the calibre of Peligot in a meeting such as that of the Academy of Science in Paris.

A surprising fact remains, namely that neither Candido's pile nor Balsamo's experiments are quoted in Callaud's contemporary treatise, neither do there seem to be traces of them in other general treatises on the subject written later. In this paper we have tried to bring them to everyone's attention again, whether experts or not.

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