The Worldwide Silicon Market and New Technologies

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ABSTRACT

The silicon metal market has had many changes in the last years. On one hand we can observe a concentration in the demand for its two main customers, the aluminium and the silicones worlds, and on the other hand new technologies like the compound ELSA electrode which has introduced changes in production costs and reduced differences to other ferroalloys. This presentation is about the market situation today in different countries and what are the perspectives using the new technologies.

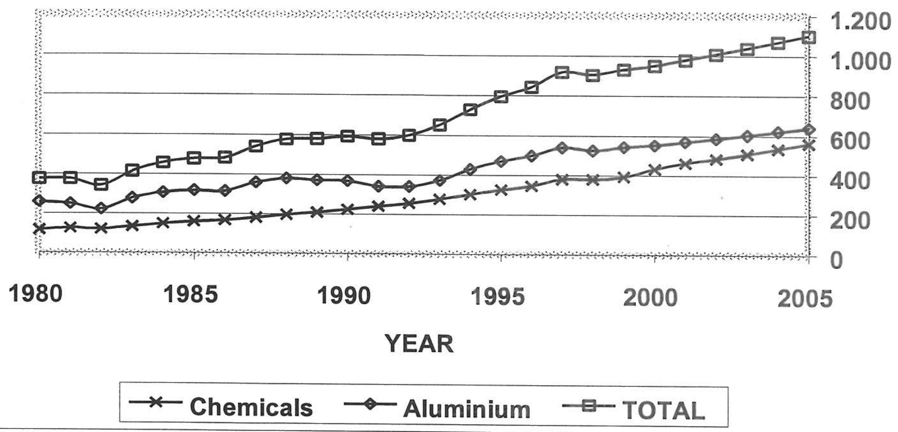
1. A PERSPECTIVE HISTORY OF THE SILICON MARKET

Over the last 20 years the silicon metal market has seen a much more spectacular rise in consumption than the rest of the ferroalloys. Aluminium alloys, its major traditional consumer, have increased by 217% in these years, but an even bigger increase has been felt in the silicones industry where it has reached 355%. By the year 2005 the demand will still be slightly higher in the aluminium world than in the silicones one. The total growth in both sectors together has been 265% over the last 20 years, is presented in figure 1.

Silicon metal is not usually included in the ferroalloys group because firstly, it should have no iron content and secondly, its market has no relationship with steel. However, the production process has many things in common with the rest of the ferroalloys and other submerged electric arc products.

There are other applications with a much greater additional value such as semiconductors and solar cells whose percentage increases are even more impressive. In all these markets, especially in the last one, silicon has always been known to have greater production difficulties, greater purity and greater technological knowledge than the common ferroalloys.

Figure 1---SILICON METAL MARKET



All analysts agree that the increase perspectives as far as silicon consumption goes will maintain this growth percentage in the coming years. New applications of silicones, closely related to the standard of living, are frequently shown by the opening up of new factories which have ever increasing demands for silicon. The aluminium world also keeps on getting bigger and, although it recycles part of the consumption, each day new applications appear, one example is that cars need to use aluminium to reduce their weight. As far as the semiconductors market goes, it is a curious fact that although its tonnage is much lower (in fact it is traded in kilos instead of tonnes) its total revenue of sales is very similar to the previous two since its price is also much higher. All these markets have a strong technological content which has progressed a lot over the last few years and big groups have been created which concentrate the demand for silicon in very few hands.

On the other hand, from the silicon producers point of view the situation is not so optimistic. Over the last 20 years prices have been submitted to tremendous fluctuations and highly marked cycles. However, taking everything into account, applying constant monetary values, prices have been reduced. The main reason has been the entry of new producer countries which have covered a good deal of the increase in demand and have atomised the offer even more without offering any technological improvements.

In the 70's the majority of the new furnaces were built in Europe, North America and South Africa. In the 80's other countries strongly broke into the market and were seriously affected by antidumping measures in Europe and America. Once cost systems were normalised, as in the Western World, these countries now also have the same difficulties as the traditional producers. In the 90's China emerged with a great many small furnaces, whose costs structures cannot be compared to the Western World but at the moment produce more than 20% of the world market.

Taken over all, in the last 20 years new producers have been created with great importance in new countries and applying different marketing rules. This has been the cause of antidumping measures, which have not impeded a fall of prices in the market. With the global economy, which we seem to be going towards faster and faster, would there still be countries which could put huge quantities of silicon on the market following marketing rules which are different to the normal ones?. It is evident that they are becoming less and less and the costs structures and the application of marketing rules will end up putting each one in its place.

Marketing rules will also show the tendency towards the concentration of the offer, the same as has been carried out with the concentration of the demand both in aluminium as in silicones. The technological and commercial advantages which the big highly specialised groups can obtain will leave the small producers out in the cold following the same laws of evolution which we see daily in the economy.

2. THE MAIN ELEMENTS IN THE COST OF SILICON

The basic raw materials for silicon metal, quartz and carbons, are similar to those for ferrosilicon, but in both cases must have a high level of purity in order to reach the specifications of the silicon. There are some impurities, such as iron, which when they get into the furnace are very difficult to eliminate afterwards, and this has a very marked effect on silicon metal production, as we will see.

Good quality quartz low in iron content is much scarcer than the quartz used in ferrosilicon. Not only is its chemical purity important but also other physical parameters, which greatly affect the running and efficiency of the furnaces. Consequently, assuring the supply of high quality quartz has been, and will be even more so in the future, a strategic factor for producing silicon.

Table-1 MAIN ELEMENTS IN THE SILICON METAL COSTS

Cost Element	Unit	Consumption unit by tm silicium				Price in Euros		
		Medium	Best	Worst	W/B%	Best	Worst	W/B%
Quartz	tm	2,800	2,600	3,000	115%	12	40	333%
Carbons	tm Fix Carbon	0,952	0,884	1,020	115%	210	270	129%
Electrodes	tm	0,100	0,080	0,120	150%	720	2.352	327%
Electric Energy	MWh/tm	12,400	11,300	13,200	117%	15	24	159%
Personnel	Man hour	9	7	16	229%	10	28	280%
Others	Euro/tm	36	30	50	167%	80	140	175%

As far as carbons go, the traditional solution of using charcoal has the disadvantages of the cost of manpower and anti-environment elements. Mineral carbons with very low ash content have substituted charcoal in many countries since manpower costs in said countries have made it too expensive. To sum up, the basic raw materials used in silicon metal production are similar to those used for ferrosilicon but much scarcer and thus much more expensive.

Of course, the main cost element in silicon metal production is electric power. Nearly all the factories have been built based on the facilities of the supply of electricity at a good price and with long term agreements. They have been built where electricity is produced cheaply or where political contracts have facilitated the industrialisation of a certain area.

Problems have always arisen when these contracts cease and open competition with other power consumers has come into being. At present, in order to get reasonable power prices, some companies have been forced to shut down their furnaces during high electric consumption periods (usually in winter), or the hours of maximum demand each day, or interrupt the running and shut down their installations when the electric power supplier so requires.

However, the greatest difference between silicon and ferrosilicon furnaces is in the electrodes. In a ferrosilicon furnace a Soderberg-type electrode can be used with a casing and steel fins, which are consumed together with the carbon. Good quality silicon metal cannot be produced this way because of the casing and steel fins. The traditional solution was to use prebaked amorphous carbon electrodes, which did not contaminate but needed a special technology for baking and mechanisation and were limited to a certain diameter size. For this reason silicon metal furnaces did not increase in size as did those of ferrosilicon and when designing a new furnace, one of the fundamental decisions was what was to be the size of the electrodes.

The main cost details for silicon metal are shown in the table 1, which only tries to study which factors are more important in the cost price of silicon. The specific consumption values shown are the maximum and minimum ones usually found in the factories. It is evident that there is never a situation with better prices and efficiency but that the factories evolve adapting their own technology to their own price situation as far as possible. There is a principle of natural compensation in such a way that when a raw material is cheap, specific consumption are high. The clearest example is that of manpower: the difference in salaries in different countries, taken in dollars, can be enormous; however, there are factories producing 40,000 Tm per year with a work force of hardly 100, while other countries use over 1000 people to get the same production. In the end the influence on the cost price always tends to compensate itself.

3. THE INFLUENCE OF TECHNOLOGY ON THE COST PRICE

Many factories in the world built 30 years ago are absolutely the same in size and production units as those built very recently. In fact, you find furnaces still running which are even older and smaller, even in the developed countries. This leads us to the conclusion that technological improvements in the production of silicon and ferroalloys in general have been really very few over the years if we compare them even with our nearest sectors, such as steelworks and aluminium.

Taking into consideration the previous table, let's carry out a calculation to study the influence of each one of the concepts on the final cost price. Thus, we present the table 2 where the first column shows the influence of the differences in specific consumption at an average price. The second column shows the influence of the prices of the different cost elements at an average specific consumption.

This table indicates that the price we can obtain from the different concepts have more influence on silicon costs than the best efficiency in the factories. In both cases the parameter which marks major differences is that relative to the metric tonnes produced per head. The second factor, at the moment, is the electrodes, both for the existing differences in the specific consumption as for the difference between the ELSA-type compound electrodes and the graphite ones, which are still used in some furnaces. It must be noticed, however, that external factors count far more than the cost price of silicon metal, and maybe even the political ones more than the technical ones. On the other hand, the cycle character in the selling price, subject to strong changes in profits, does little to encourage technological improvements and could leave the companies with the sensation that the most important thing is to survive, using the basis of special external factors. There have recently been evident examples of this: one of the main silicon-producing countries devalued its currency by almost 100% in less than one month with the result that a ruinous situation became a profitable one in less than a month in that country. We are going through the opposite case in the year 2000 in the United States where the high parity of the dollar against the Euro has placed its main producers below profit level.

Table 2- DIFFERENCES IN SILICON METAL COSTS IN EUROS

Cost Element	Unit	Difference by technical results	Difference by price elements
Quartz	tm	10	78
Carbons	tm Fix Carbon	33	57
Electrodes	tm	61	163
Electric Energy	MWh/tm	37	110
Personnel	Man hour	171	162
Others	Euro/tm	313	571
TOTAL	Euro/Tm	615	1.064

In time, these external factors tend to balance themselves out and it is true that the companies which survive in the long run are those which count on a healthy financial structure, with better flexibility in their structuring and better technology in their installations, in this order.

Technology is a fundamental factor in reducing production costs and is practically the only factor which can be managed internally in the ambit of the companies. This is the reason why the technology which companies have developed has been jealously guarded as a protection for themselves to confront the competition from the external factors before mentioned. This closed attitude is perhaps the main reason why silicon production technology and ferroalloys technology in general have been developed very little compared to other sectors such as steel, aluminium or silicones.

Ferroatlántica has managed to develop new technology for the making of silicon metal. This technology has been sold to its competitors. Our basic aim is the production and selling of ferroalloys but, besides this, we have an independent company, Ferroatlántica I&D, which has already developed and sold new technology in the electrodes field and we are still developing others which we will now describe.

4. NEW TECHNOLOGIES OF FERROATLANTICA IN THE PRODUCTION OF SILICON

4.1. The ELSA Electrode

At the last INFACON Congress 8 in Peking (Beijing) we had the opportunity to explain in detail the advantages of this type of electrode presented in figure 2. We now just want to go over the main points:

- The cost of this type of electrode is approximately 45% of that of prebaked electrodes.

- It has a greater awailability since Soderberg-type paste and carbon electrode producers are much more abundant than prebaked ones.

- The changeover from making silicon to ferrosilicon can be done almost immediately.

At the moment, world silicon production as far as types of electrodes go is as follows:

ELSA - Compound Electrode	230.000 tm
Graphite Electrode	220.000 tm
Prebaked Electrode	400.000 tm
Other Types of Electrodes	140.000 tm

The main prebaked electrode makers have lowered their prices in order to confront the development of the ELSA electrode on one hand and the new prebaked electrode makers which have arisen on the other. Ferroatlántica is convinced that in the near future the rules of market economy will end up imposing themselves and the future of silicon electrodes will be based on the Soderberg-type paste the same as in the rest of the ferroalloys. Prebaked electrodes will tend to disappear, the same as graphite electrodes have not been used in silicon production in Europe and America since many years ago.

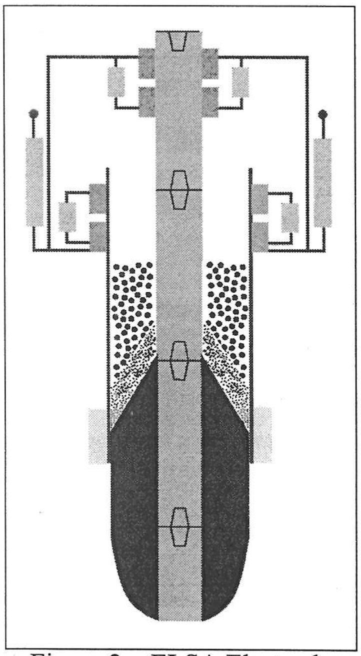


Figure 2 – ELSA Electrode

With the ELSA-compound electrode, furnaces in the future will increase in size in order to reduce personnel costs. Silicon will follow the way Ferrosilicon has gone since years back and it will be normal to see 30-35 Mw furnaces, which at present do not exist.

Together with the ELSA electrode technology, at Ferroatlántica we have developed an important mathematical model of the electrode in collaboration with the Applied Mathematics Department of Santiago de Compostela University. At the last Silicon Congress for the Chemical Industry V in Norway . we showed this model in detail example in figure 3. Feeding the data into a computer programme we obtained the answers to how the baking of the electrode is developed and of all the electrical and mechanical parameters throughout the column.

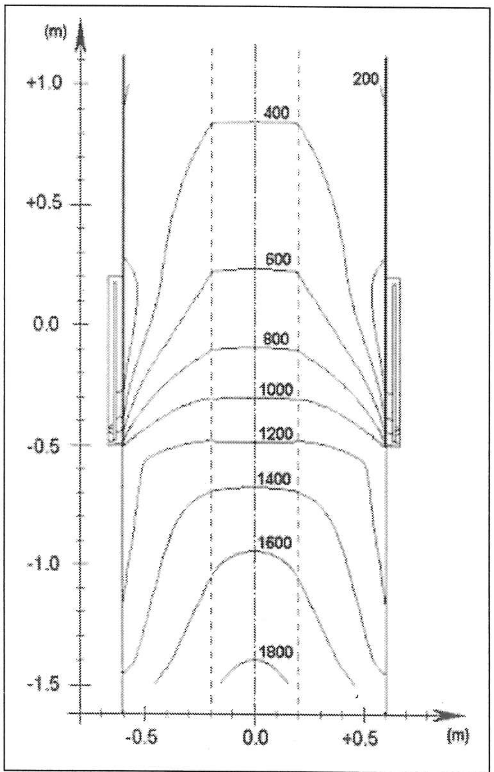


Figure 3 – Isotherm lines on the ELSA Electrode

At the same time, and with the same University, we have studied in depth the behaviour of the Soderberg-type paste on the electrodes in the ferroalloys furnaces. Soderberg paste is a complex element and fundamental in the behaviour of electrodes. For the consumers, it is very difficult to predict what is going to be the behaviour of a paste on the electrode before carrying out a real test in the furnace, with the subsequent risk which this type of test runs. Thus, we have developed a series of analyses, which show us why some pastes behave better than others do, and which are the parameters to have in mind and to improve their uses on the electrodes. Using this paste laboratory we have got to know and been able to predict much better the behaviour of this fundamental raw material.

4.2. Automation and Control of Production Process.

The introduction of computer technologies in the process is one of the few novelties that differentiate a furnace built 25 year ago and one built today. Programmable logic controller technology and computers have been installed and are getting magnificent results on the knowledge of the making process and the running of the furnaces. The control of the running capacity in the furnaces, the control and slipping of the electrodes, and the adjustments in the weighing of raw materials are normally carried out by PLC and computers. The generation of computers with powerful data bases has taken over the traditional control of these fundamental parameters and allows for detailed studies of the running of the furnaces. At present, a control panel in these factories simply consists of a computer screen and an emergency button through which all data are controlled from, not only in the furnace but also in the entire factory, which makes it a much more economical solution than traditional control panels.

Years ago, at Ferroatlántica, we opted for the development of our own technology which was first applied to the silicon factory and later on to the rest of the factories in the group. Here is an example: before installing the ELSA electrode in a furnace of our customer, we insist on all the processes which have to do with the electrode being controlled by PLC, and, if the customer so wishes, we are willing to collaborate in this development.

4.3. New systems in casting

The process which silicon goes through, from when it comes out of the furnace taphole until it is sent to the customer, involves a very important additional cost due to the generation of fines and maintenance of the milling and classification installations. Traditional processes of cooling in billet-molds also produce important segregation of impurities which are not wanted by certain customers such as silicones makers.

Some silicon producers for silicones use systems of water granulation which have the advantage of giving homogeneity to the product but which also have the inconveniences of explosions and exploitation costs.

The line of work we are carrying at Ferroatlántica we call "continuous ferroalloys casting" and has the objective of minimising the losses between the molten metal and the final product. We use a rapid cooling line over copper plates, which means that the product is cold just a few minutes after being cast and with the size desired by the customer. This system has certain similarities with continuous casting in steelworks and may be applied to all ferroalloys, being specially profitable when producing silicon for chemical purposes.

4.4. Electric Parameters for the Running of the Furnace.

We are transferring our experience with the ELSA electrode and with the development of the mathematical models to the knowledge of the state of the running of a furnace based on its electrical characteristics. These new technologies allow for very sophisticated measurement systems. Thus, very complex data bases can be carried out using the computers, from which you can get to know analyses of the state of the electrodes and furnaces in much greater detail.

The aim of all this is to reduce specific power consumption and to detect as soon as possible any metallurgic problems arising in the furnace, either because of a change of raw materials or problems with the casting.

5. CONCLUSIONS

The demand for silicon metal keeps on increasing very quickly. Because of non-technical factors, prices have not followed this increase in demand and this has given place to a serious technological underdevelopment in the entire sector. Ferroatlántica has taken part in technical improvement by means of the installing of the ELSA compound electrode and continues developing technologies on being convinced that in the very near future companies will be more competitive due to technology than any other external factors.

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