The SKTEC electrode

An adaptable electrode design for the production of silicon metal and ferro-silicon

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ABSTRACT

The use of self-baking (also called Söderberg) electrodes for the production of ferro-alloys and in particular ferro-silicon, has been known for about 75 years. Due to iron contamination from the casing and the fins, this electrode cannot be used for the production of silicon metal. Many attempts have been undertaken to develop a type of Söderberg electrode which would allow a cheaper production of silicon metal while meeting all the criteria for reducing the amount of iron in the produced metal. The most successful design has been disclosed by Persson in March 1986 and further refined and developed by Ferro-Atlantica of Spain. This system is in use in at least 14 furnaces producing silicon metal in 5 different countries, among them, in the SiMet furnaces of our Bécancour Silicon Plant. A hardware retrofitting is required for this type of electrode.

The SKTEC electrode is different as it can be used directly in ferro-silicon furnaces with self-baking electrodes without any modification to the existing or addition of another slipping system. The SKTEC electrode allows very flexible product changes as the same furnace can produce both FeSi of any grade and SiMet without any downtime between the gradual change from one product to the other. The lowest electrode cost can be obtained for each of the two product groups without any expensive removal or destruction of the electrode in or underneath the slipping devices.

The SKTEC electrode overcomes the problems associated with prior art of one or the other: silicon metal contamination, core breakages as a result of extrusion forces, casing deformation, loss of production and capital expense for installation of new slipping systems. It also provides a way to use bigger and more efficient ferro-silicon Söderberg-type furnaces for even temporary SiMet production, instead of using silicon metal furnaces with pre-baked electrode technology or incurring hardware with costs to change to composite electrodes and then losing the flexibility to return to FeSi campaigns. It allows furthermore the application of injection technology, already known for Söderberg electrodes, to be used without any added costs to the electrode in SiMet production.

INTRODUCTION

Since a major overhaul of our FeSi 75% furnace #2 in October 1997, the SKTEC electrode design has been used with success for the production of silicon metal during a total of 34 months. Our design also enabled the production of ferro-silicon with Söderberg electrodes for a total of 8 months in 4 campaigns switching back and forth from the two different electrode types without downtime.(Chart 1)

Various experiments in 1996 and 1997 showed that a new self-baking electrode could be defined and implemented for full-time operation without the restriction so far known for Söderberg electrodes in high silicon level production. We filed for patent priority in Canada in May 1997 and had our USA patent granted in December 1998[1]. We also hold a South African patent, and have applied for a patent in most countries with significant ferrosilicon production.

We have documented in the past some of the results obtained for quality and furnace operation[2], but would like here to describe the characteristics of the electrode design itself.

1. GENERAL DESCRIPTION

As goes the saying "Necessity is the mother of invention", the development of the SKTEC electrode begins with the necessity of finding different products and customers for our FeSi 75% ferro-silicon furnace in 1996.

Bécancour Silicon strategy has been for a long time to move away from commodities and be recognized as a producer of speciality products. The conversion of our two silicon metal furnaces in 1994 and 1996 to the composite electrode technology and our experience with the Söderberg electrode since 1976 enabled us to develop new ideas and completely change the product base of our ferro-silicon furnace.

The SKTEC electrode is described in details in our patent application. The major features which differentiate this design from the composite electrode are:

- capability to switch to and from Söderberg electrodes;
- no extrusion of electrode from the casing;
- no additional slipping mechanism or hardware retrofit required;
- no capital expense or shutdown for installation;
- lower electrode cost.

It is also different from the Söderberg design:

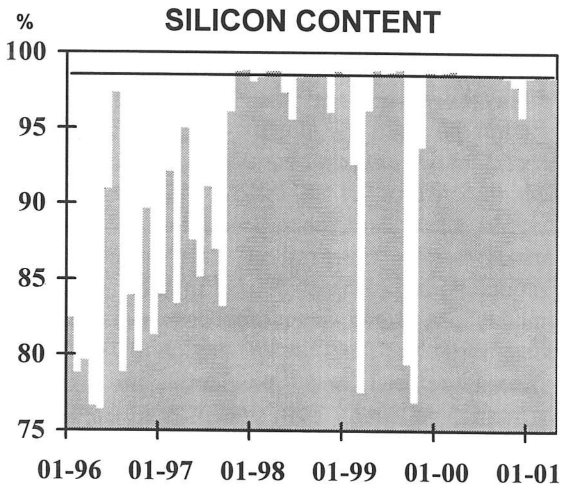
- elimination of fins for baking purposes;
- increased baking capacity for SiMe production;
- drastic reduction in iron contamination;
- increased thermal shock resistance.

It can be described as a composite electrode where the core instead of being held by an additional slipping mechanism is attached to the casing at regular intervals by a consumable suspension system. No hardware modification or additional fixed cost are required to convert a Söderberg electrode to the SKTEC design. Compared to the Söderberg design, it is a variable cost change due to the additional core, and a different casing and paste.

2. PRODUCT SPECIFICATION

The production of silicon metal with regular Söderberg electrodes is limited by the maximum iron content specified by customers. In general an iron content below 1% is the limit between silicon metal and ferro-silicon and cannot be attained on a regular basis with Söderberg electrodes. The casing itself and the fins can be modified to lower the iron level but mechanical strength and baking capacity prevent the regular Söderberg design to be used for the production of silicon metal.

CHART 1



For example a furnace with Söderberg electrodes and using mainly metallurgical coal as a reducer would produce metal with a minimum 1,3% iron content, including a contribution of approximately 1% from the electrodes. A radical change is needed to lower iron contamination. The removal of fins and changes to the casing are part of the SKTEC design and enable to adjust iron level to the customer specifications.

3. BAKING CAPACITY

In addition to the limit on iron level, a Söderberg electrode will generally not have enough baking capacity for the production of silicon metal. These two characteristics are also in opposition as an increase in baking capacity will normally be accomplished by raising the iron content in the electrode from fins and casing changes.

Instead of using fins to carry the necessary heat to bake the center of electrodes, the SKTEC design use a pre-baked core. The core also replace the fins to hold the baked electrode below the electrical current contact plates.

As an example, our regular Söderberg design has a baking capacity of less than 10 gr./KA^2/hour while the SKTEC design has a baking capacity in excess of 14 gr./KA^2/hour an improvement of more than 40%.

The difference is even more pronounced in the rare case where a long slip or accelerated slipping is required after an electrode breakage in the furnace.

4. ADAPTABILITY

Bécancour Silicon Inc. being a one-plant company with many different customers has to be able to switch from a given specification to another very effectively. As a supplier of quality we also insist in producing material in campaigns to ensure less variation as possible for our customers. The SKTEC design allows us a much broader range of products at the minimum electrode cost.

Good planning is required as changes made on electrodes at the top floor of the furnace building will be effective approximately three weeks later in the furnace. This adaptability is however extremely important to adjust our production to market conditions.

5. COSTS

As explained earlier, one of the major advantage of the SKTEC electrode is the fact that no shutdown or hardware installation is required. The evaluation of this advantage will vary from plant to plant but can easily reach more than a million $US.

The variable cost of the SKTEC electrode is lower that the cost for the composite electrode. In the case of the composite electrode it is extremely important to use only the highest quality of graphite as the core material. Our experience and many tests have shown that the price of core for the SKTEC design can be lowered by the use of a different graphite quality. As the cost for the core will typically represent half of the total electrode cost, it is a very important factor.

The SKTEC design will also allow the use of a smaller core than the composite electrode which is another very important factor considering the major difference in price between graphite electrodes and electrode paste. Another major advantage is the reduced risk of electrode breakages above the electrical contact plates.

6. MECHANICAL STRENGTH

As with the composite electrode, the SKTEC design has an excellent thermal shock resistance compared to a pre-baked carbon or a regular Söderberg electrode. This characteristic is a result of the stability of the graphite core and the very high current-carrying capacity.

One major advantage of the SKTEC design is that no extrusion of the baked paste out of the casing takes place. The extrusion process result at times in damages to the baked paste that combined with the presence of a joint between two graphite electrodes can cause an electrode breakage after a thermal or mechanical shock.

The extrusion process in the composite electrode can also results in breakage of the graphite core high in the column due to bending forces. This possibility is eliminated with the SKTEC design as no extrusion takes place. This is the major reason explaining that a core with a lower flexural strength and lower cost can be used with the SKTEC design.

CHART 2

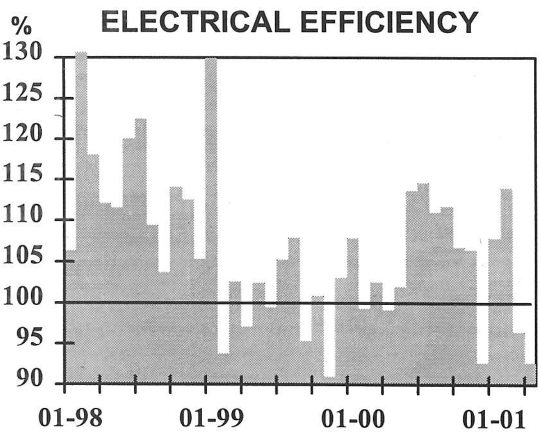
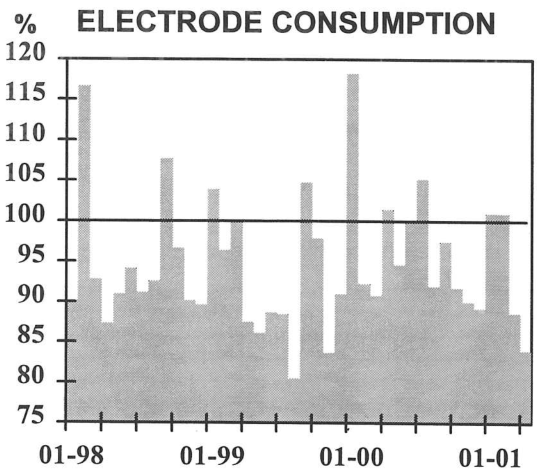


CHART 3



7. FURNACE PERFORMANCE

Furnace #2 in Bécancour is probably the largest three electrode silicon metal furnace in operation. A comparison with our SiMe furnaces #3 and 4 shows improved electrical efficiency and lower electrode consumption, two of the most important parameters in furnace operation.(Chart 2-3)

The silicon recovery and raw material usage are comparable and the better electrical efficiency can be explained by a higher reaction rate. The throughput of raw material is higher than the proportionally higher furnace load would predict.

CONCLUSION

Many different quality of silicon metal have been produced in trial runs. The possibility of producing for these specifications at a commercial level has thus been evaluated. The output of furnace #2 can be adjusted in the future to different market conditions.

We are also still evaluating different core material with the objective of further reduction in cost. The reliability of the system has been improved since mid-2000 to a level comparable with our composite electrode experience.

We believe that our furnace #2 operation with the SKTEC electrode now represents a benchmark for silicon metal production.

REFERENCES

1. Boisvert et al. U.S. Patent 5,854,807 (filed 27.10.1997).

2. Boisvert R., Ksinsik D. The SKTEC process, Silicon for the chemical industry V, Tromso, Norway, 2000.