INFACON 7, Trondheim, Norway, June 1995
Eds.: Tuset, Tveit and Page
Publishers: FFF, Trondheim, Norway

DEVELOPMENT OF AN IN SITU PREBAKING ELECTRODE SYSTEM FOR SILICON METAL PRODUCTION

Arnfinn Vatland[1] and William Bruff[2]
[1]Elkem a/s Research, Carbon, P.O.Box 40 Vågsbygd, N-4602 Kristiansand, Norway

[2]Lerkeveien 7, N-4622 Kristiansand, Norway

ABSTRACT

A prebaked carbon electrode system developed by Elkem a/s in Norway is now in regular operation on silicon metal furnaces. The incorporation of the baking process into the silicon production furnace has reduced the electrode costs compared to the conventional off-furnace manufactured prebaked electrodes. The changeover with the introduction of an additional process and new equipment on the electrodes has been successful. The development efforts and results are included.

INTRODUCTION

The Søderberg process for formation of carbon electrodes in situ in electric furnaces is very well known. In general, the Søderberg process overcomes the need for manufacturing electrodes in a separate manufacturing facility by enabling the production of the electrode in situ from an unbaked electrode paste comprising a particulate carbon material and a carbonaceous binder.

The Søderberg electrodes in electrothermic furnaces are typically equipped with a consumable casing which follows the downward movement of the electrode into the charge. The electric current is supplied to the casing of the electrode both for baking the electrode paste as it progresses downward toward the charge and for supplying operating current to the electrode.

Unfortunately, the continuous Søderberg electrode is not permitted for silicon metal production for the following reasons:

- The product will be contaminated by the high iron content of the casing material.
- Depending on the energy utilized for the smelting process the baking rate of carbon electrodes is slow compared with the consumption rate in silicon metal furnaces.

For silicon metal production it is most common to use the conventional off-furnace manufactured prebaked electrodes. Their level of chemical purity is high to avoid polluting the end product. The electrode column contains several large pieces each joined together. In this way the electrode can be consumed at a rapid rate, i.e. twice that of an electrode in 75% ferrosilicon operation. The joints are the weak points in the column during operation, and therefore costly accurate machining, special precautions during transportation, special mounting procedure and good electrode material characteristics are required to avoid electrode breakage. The prebaked electrode cost is two to three times that of the Søderberg electrode cost.

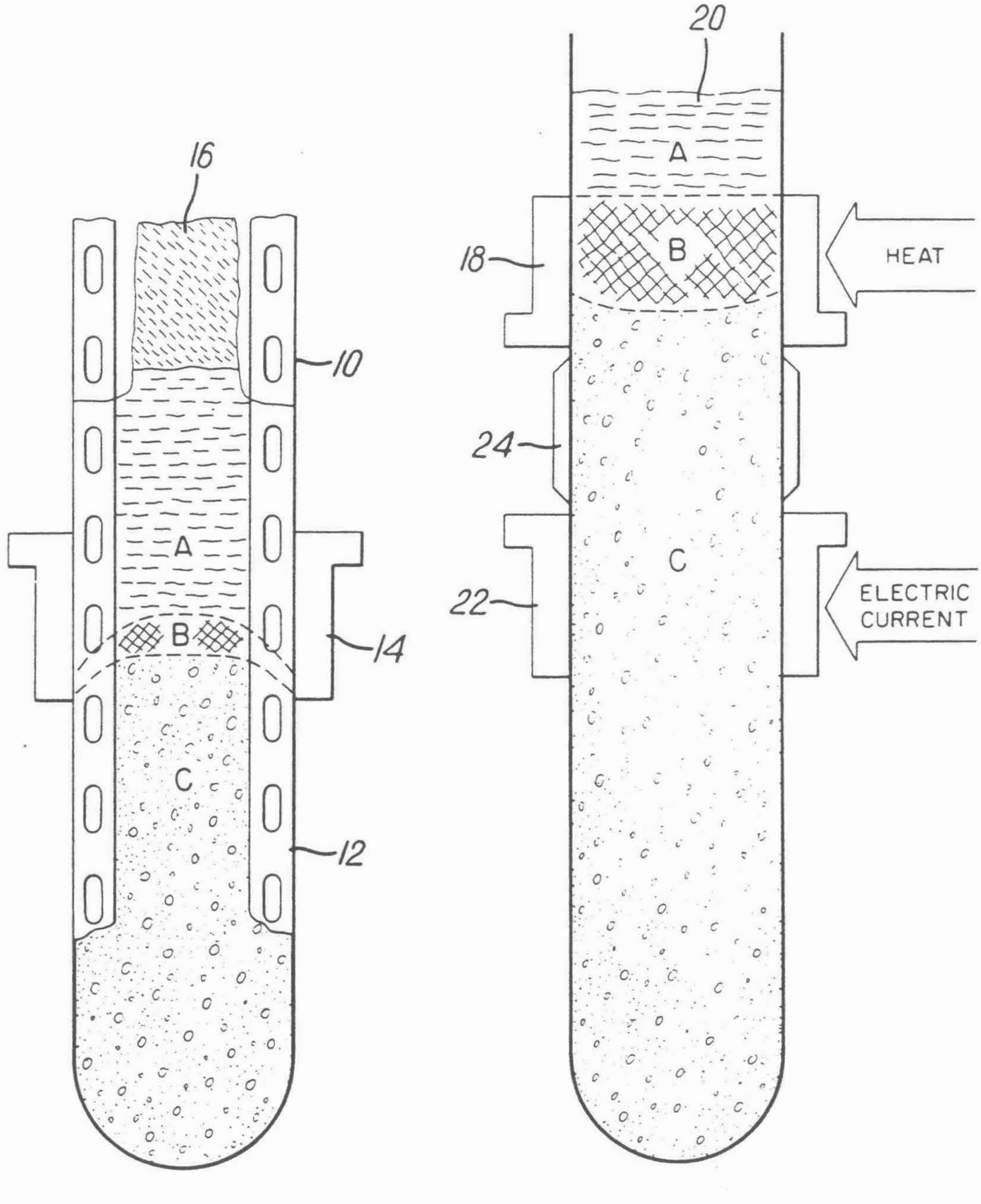
The present paper deals mainly with the R&D-activities by Elkem a/s in Norway in connection with an improved in situ prebaking electrode system for silicon metal production. Elkem a/s as a producer of silicon metal, electrode paste and a supplier of electric reduction furnace equipment has put a lot of efforts into The Bruff Electrode. Now the system is in regular operation on silicon metal furnaces representing in our case an alternative to the other carbon electrode systems for the production of low iron silicon.

A few years ago C. F. Fulgenzi presented a status of the most interesting new carbon electrode systems [1]. He told of the hundreds of reported efforts to develop better carbon electrodes of which only three have shown outstanding progress and promise for commercial use: The Cavigli System, The Persson Electrode, and The Bruff Concept.

DESCRIPTION

The method relates to an improved process for the manufacture of electrodes in situ, and more particularly to an improved process of forming a carbon electrode in the upper parts of electro-metallurgical furnaces [2]. FIG. 1 shows a schematic view of a longitudinal section of an electrode of the conventional Søderberg process, and of an electrode in accordance with the improved process.

U.S. Patent Jul. 9, 1985 4,527,329



PRIOR ART

FIG. 1. Schematic View of the Søderberg Process (Prior Art) and of the Improved Process for the Manufacture of Carbon Electrodes.

As shown in FIG. 1, the continuous in situ prebaked electrode is obtained by the process of softening and baking an electrode paste in a relatively small first zone which provides for controllable heating and baking of the electrode paste. The baked electrode advances from the first heating zone to a second one with the contact clamps which supply electric current to the electrode. In this way the heat for the baking process is independent of the energy utilized for the smelting process in the electric furnace. This separation of the two processes makes it possible to achieve a fast baking electrode to exceed the consumption rate of the carbon electrode in silicon metal operation.

The heat in the first zone is adjusted until the paste is baked sufficiently solid and strong so that the suspension of the electrode and slipping can be effected by a separate holder disposed between the primary and the secondary zone.

In order to obtain controllable heating in the first zone a baking furnace is installed [3]. FIG. 2 shows schematically the baking furnace to which the energy utilized for baking of the electrode has to be supplied from an external source.

The method for baking of the carbon electrode is as follows:

1. The electrode paste is formed into a simplified steel casing without internal fins in order to reduce manufacturing costs of such casings.

2. The casing which is filled with unbaked electrode paste is slowly and continuously or intermittently lowered down through the baking furnace.

3. The gases which evolve when heating the electrode paste will flow into the baking furnace through the perforated casing. By supplying air, the gases burn in the baking furnace. The total amount of supplied external energy and energy generated by burning of the baking gases is sufficient to maintain a baking furnace temperature between 700^{o} and 1300^{o} C.

4. The casing is removed from the baked carbon body below the baking furnace.

The baking furnace including equipment for cutting off the used casing is arranged above the suspension system of the electrode in the electric furnace. In this way the product which is produced in the smelting furnace is not contaminated by the iron of the steel casing.

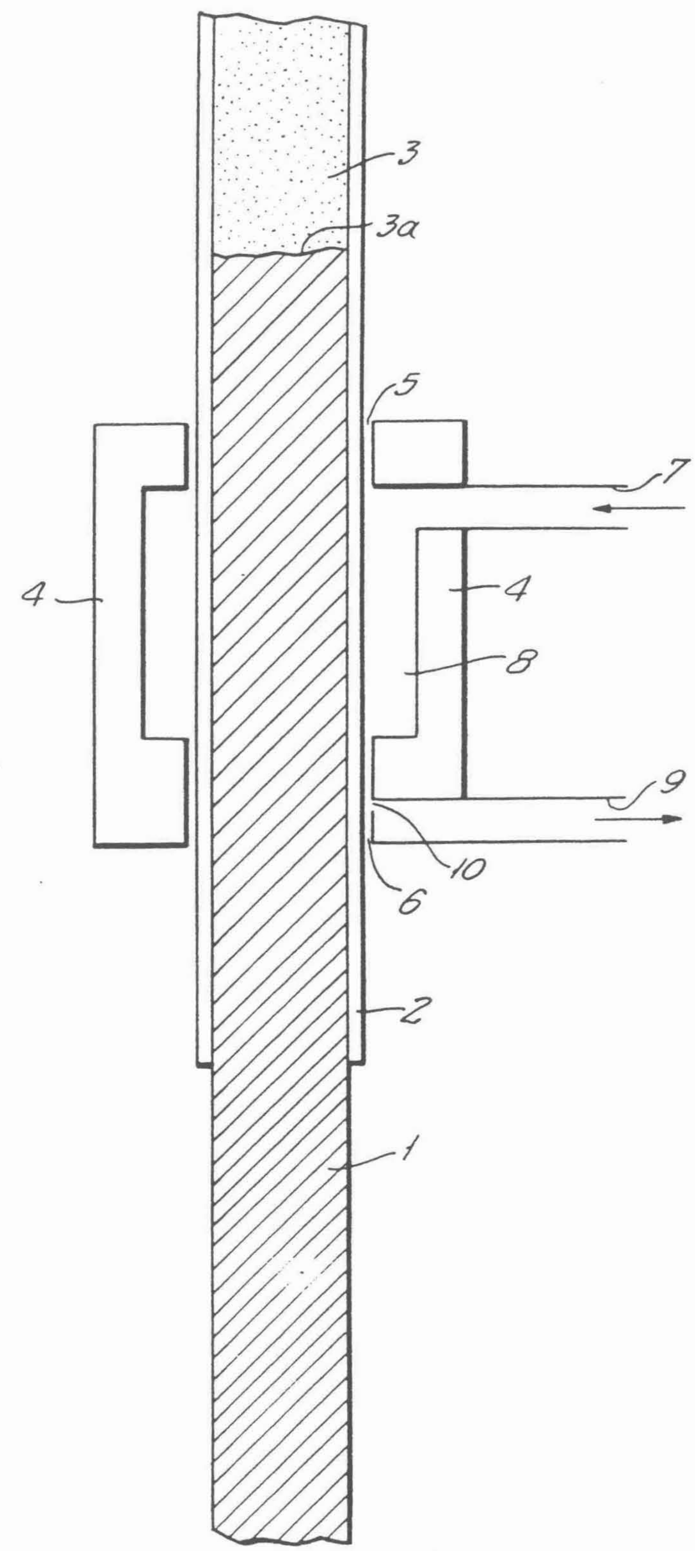


FIG. 2. Schematic View of a Baking Furnace for the Production of Carbon Electrodes.

RESEARCH AND DEVELOPMENT

General

The idea of the improved in situ prebaking electrode concept was presented inside the company in 1968. However, for various reasons research activities did not start before one decade later.

As the concept was new and unproven one decided to try out the system step-by-step. The objective was to incorporate the baking process on an existing silicon production furnace equipped with the conventional off-furnace manufactured prebaked electrodes. Hence, the changeover had to include the introduction of an additional process and new equipment on the electrodes.

Baking Furnace

In 1977 calculations with Elkem´s electrode temperature model indicated good possibilities for the baking of an electrode in a relatively small baking furnace.

In 1979 the experiments started in the pilot plant where a self-constructed baking furnace was tested out on a 355 mm (14") diameter electrode. The baking process was promising, and the electrode was able to conduct electric current in a single-phase pilot smelting furnace.

Encouraged by the results the testing in the pilot plant continued, and the baking furnace and the electrode were increased step-by-step up to 1400 mm (55") in diameter.

During operation of the baking furnace, for some weeks a hard carbonized material was built up in the upper part of it. Because of this strong material it was not possible to move the electrode relative to the baking furnace, and the process had to be stopped in order to remove the layer of carbonized material. This serious problem was overcome by arranging a cooling chamber, for circulation of a cooling medium, between the upper part of the refractory lining and the carbon body which is being produced [4].

Movement and Suspension of Baking Furnace

The first version of the in situ prebaking system was installed in 1983 on one of the electrodes of a three-phase silicon furnace at Elkem Fiskaa Silicon plant in Kristiansand. The electrode diameter was 890 mm (35").

The principle of producing an electrode fast and independently of the energy utilized for the smelting process, was to be tried out by a suspension arrangement in which the baking furnace can be moved, on to the electrode. To be prepared for an electrode breakage, the equipment was designed to keep a reserve of about 2 meters of extra baked electrode in the column.

The result of this first construction was promising, but during long-term operation serious problems occurred due to deviation from a straight-lined electrode. After a few adjustments, convincing results were achieved for the actual phase, i.e. 270 days without any electrode breakage.

Based on all experience gathered from the first installation, a second version of the in situ prebaking system was introduced, and has been in regular operation on all three electrodes for many years on another silicon furnace with 900 mm (35.43") columns [5]. FIG. 3 shows a schematic view of an electrode in an electric furnace with the arrangement for movement and suspension of the baking furnace.

FIG. 3 illustrates a baking furnace with a frame which is fixed to the electrode suspension system. From the top of the baking furnace frame three rails, in the form of spindles with threads, are suspended to enable the baking furnace to move up or down.

In order to produce a homogeneous electrode the following is important regarding baking furnace movement:

- The baking furnace is moving continuously or intermittently, on to the electrode, with a velocity which corresponds to a pre-set baking speed for the electrode.

- The movement of the baking furnace is interconnected with the electrode slipping equipment in such a way that when the electrode is slipped a certain increment through the holding and slipping rings, the baking furnace will automatically be moved an equal distance downwards.

- When an electrode breakage, or high rate of consumption occurs, the baking furnace will be moved downwards to a low position on to the electrode, which means less reserve of baked electrode. A maximum permitted baking speed is then used to gain the normal position.

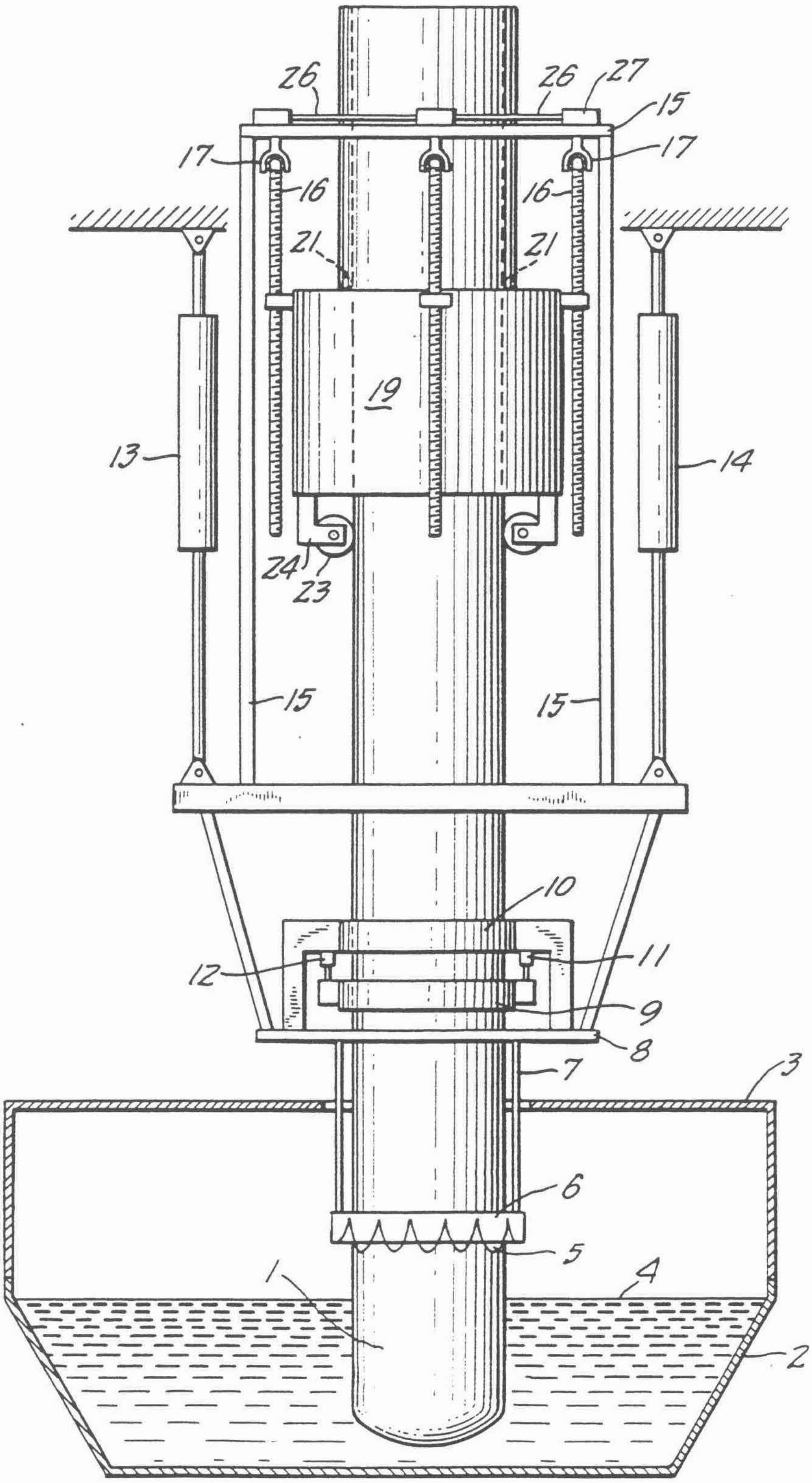


FIG. 3. Schematic View of an Electrode in an Electric Furnace with the Arrangement for Movement and Suspension of a Baking Furnace.

As the electrode has to pass through three fixed points in the column, namely the baking furnace, the electrode holding and slipping equipment, and the current clamps, any deviation from straight-lined electrode will result in clamping or sticking of the electrode. The electrode will thus either break at a point between the three fixed points which it runs through or it will be impossible to slip the electrode through the electrode holder. This serious problem was overcome by the new arrangement for suspension of the baking furnace.

Cutting off Electrode Casing

In order to cut and remove the used steel casing below the baking furnace, the operators from the beginning used a cutting torch or angular milling cutter. Due to limited free space in the area of the electrodes above the furnace roof and the danger of short-circuiting, the furnace operators usually are not allowed to work in this area when the furnace is running. It is therefore necessary to shut down the furnace when operators are cutting off the electrode casing manually.

A device for cutting the electrode casing has been developed [6]. By using this device the casing is automatically cut both vertically and horizontally; then the casing can be removed in form of relatively small pieces.

CONCLUSIONS

For many years a lot of efforts have been put into the development of an in situ prebaking electrode system for silicon metal production, based on the idea of installing a baking furnace in the upper part of the electrode column and using a simplified steel casing which is removed from the carbon body below the baking furnace.

This has led to the following conclusions:

- A practical and working electrode system is in regular operation on silicon metal furnaces, representing in our case an alternative to the conventional off-furnace manufactured prebaked electrodes.

- The incorporation of the baking process into the smelting furnace has reduced the electrode costs to less than half the costs of the prebaked electrode.

- The baking rate is sufficient to exceed the consumption rate of carbon electrode in silicon metal operation.

- When an electrode breakage, or high rate of consumption occurs, the reserve of about 2 meters of extra baked electrode kept in the column, is utilized. Therefore, even in such cases, compared to prebaked there are no extra losses of metal production in the smelting furnace.

- The product which is produced in the smelting furnace is not contaminated by the iron of the steel casing.

- It is not necessary to shut down the smelting furnace operation when cutting off and removing the used electrode casing.

The changeover with the introduction of an additional process and new equipment on the electrodes has been successful. However, to avoid setbacks it is also important to focus consistently on the baking process and the electrode equipment in the same proper way as it is done in the case of the smelting process and the electric furnace.

REFERENCES

1. C. F. Fulgenzi, "New Electrodes for Arc Furnaces", The ABM Conference, Vitoria, Brazil, December 1992.

2. W. Bruff, G. S. Santana, and D. G. Oliveira, Process for the Manufacture "In Situ" of Carbon Electrodes. U. S. Patent 4,527,329. Appl. Jul. 12, 1982: Acc. Jul. 9, 1985.

3. W. Bruff and L. Olsen, Method for Continuous Production of Elongated Carbon Bodies. U. S. Patent 4,612,151. Appl. Nov. 5, 1984: Acc. Sep. 16, 1986.

4. E. Q. Dahl, A. Vatland, and O. T. Vegge, Baking Furnace for Electrodes. U. S. Patent 4,678,434. Appl. Aug. 7, 1986: Acc. Jul. 7, 1987.

5. H. M. Kvivik, Arrangement for Suspension of a Baking Furnace for Electrodes. U. S. Patent 4,722,684. Appl. Jul. 14, 1986: Acc. Feb. 2, 1988.

6. O. T. Vegge, Device for Cutting an Electrode Casing. U. S. Patent 4,663,844. Appl. Apr. 28, 1986: Acc. May 12, 1987.