# A MORE EFFICIENT FERRO-SILICON PROCESS

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## ABSTRACT

After nearly ten years of development work the Closed 75% Ferrosilicon Furnace has been successfully concluded. Operational problems have been solved through the utilization of the Split Furnace Concept.

We have experienced reduced carbon consumption, high silicon recovery and very good operating conditions.

To handle the environmental requirements of the off-gases from the closed furnace, we have successfully solved the problem of high temperature cleaning the gas. This enables us to utilize this gas for various purposes and with high efficiency.

For special application when the furnace gas is utilized for steam production and possible subsequent regeneration of electric power, we have successfully developed a system where uncleaned gas is used directly as fuel in a specially designed steam boiler. The exaust gases are cleaned in a conventional Bag House filter.

The system is simple and gives higher efficiency than a corresponding waste heat boiler system for semi-open furnaces.

We are on the threshold of a much more efficient silicon process.

# A MORE ENERGY EFFICIENT FERRO SILICON PROCESS

## INTRODUCTION

After several years of development, the closed 75% ferrosilicon furnace has been accomplished and brought to a successful conclusion. (1, 13)

The high grade ferrosilicon process is a high temperature process which requires special technique for operation through stoking of the charge to reduce crust formations. (2, 3, 15)

This meant that a method for stoking the furnace through the cover had to be found which was efficient and required a minimum of maintenance. This has been achieved through the invention of the Split Furnace Concept. The technique has been reported in several papers. (1, 5, 13, 14, 16)

These papers mainly describe achievements obtained with the Split Furnace Concept applied to various open, semi-open and closed high grade ferrosilicon furnaces.

The following Table No.I sums up the furnaces presently equipped with the Split Furnace Concept in the world to-day (1982).

Table No. I, Ferro-alloy smelting furnaces with ELKEM SPLIT FURNACE CONCEPT 1982.

| Furnace type | Product | Load MW | Start furnace | Remarks |
|---|---|---|---|---|
| Open | Si-metal | 9 | 1977 | |
| Semi-open | Si-metal | 20 | 1980-81 | |
| Open | 75/90% FeSi | 30 | 1978 | |
| Closed | 75 % FeSi | 8.5 | 1977 | |
| Semi-open | 75 % FeSi | 35-40 | 1980 | |
| Closed | SiMn | 18 | 1981 | 100 % Charcoal |

The ring very efficiently reduces the crust formation and makes the charge porous. The ring, however, does not distribute the charge as efficiently on the top of the furnace as obtained with the stoker. Special care must therefore be taken into consideration in the design of the charge system to ensure correct location of the discharge points.

Our experience with the operation of a closed 75% FeSi furnace is that the gas temperature under the cover correlates well with the silicon losses, and that the furnace condition can be better judged by temperature observation than by visual observation of an open furnace

Closed furnace operation of 75% FeSi has yielded reduced carbon consumption and very satisfactory operating conditions.

Parallel with the development of the closed furnace, it was necessary to study and find solutions for the off-gas treatment of a highly combustible gas, and possible utilization of this valuable gas in an energy recovery system.

In this paper we will present our summing up of the operation of a closed 75% ferro silicon furnace over the last 5 years, and our development work with the Elkem High Temperature Filter as well as the development of a pilot steam boiler for using uncleaned CO-gas.

The development work with the closed 8.5 MW, 75% FeSi furnace has shown that the ferrosilicon process can be made much more efficient.

## THE CLOSED 75% FERROSILICON FURNACE.

The principle of the Split Furnace Concept has been described in several papers, (1, 5, 13, 14, 16) and should only briefly be recapitulated here.

The main objectives with the Split Furnace Concept are to eliminate the stoking process, to prevent bridge formation and to obtain a charge porosity which will increase permeability of the charge, thus give a better gas distribution which will benefit the smelting process.

By dividing the crucible in two parts which can rotate independently, these important objectives have been attained.

The upper part or "the ring" can be given various shapes and geometries. As discussed in Mr. Tveit et al. paper (14), it is very important to find a refractory lining material which will give a certain life time (one year) and a lining easy to change or repair during scheduled shut down.

This problem has to a large extent been solved by using precast blocks. However, time is required to find the best refractory material.

The operation of the 8.5 MW 75% FeSi furnace at our Bremanger Plant, has thus been very satisfactory over the last 5 years. The installation is shown in Fig. No. 1.

## RAW MATERIALS

The raw materials used in the closed ferrosilicon furnace are ordinary materials for the production of 75% ferrosilicon without woodchips. (13)

Consumption figures and screen sizes are shown in the Table No. II.

Table II. Raw Materials and Screen Size

| Material | Consumption kg/metric ton 75% FeSi | Screen size average, mm |
|---|---|---|
| Quartz | 1740 | 8-100 |
| Coke | 611 | 0-20, 5 % - 3 |
| Coal | 449 | 0-30, 5 % - 3 |
| Iron pellets | 282 | 10-20 |

OPERATION

The closed furnace has been operated on 75% FeSi all through the last 5 years, except for short non-conclusive periods on 90% FeSi.

The electrical conditions in these periods have been on average

- electrical current 48KA
- resistant 1.2 milliohm

An important parameter in the closed furnace operation is the temperature variation, which will, for a good operation, be in a range of 500 - 700°C. During poor operation the temperature might rise to 1200°C or more.

There has been found a very good correlation between the gas temperature and the silicon losses, and this important feature makes its easier for the furnace operator to judge the conditions of a furnace than visual observation of an open top furnace.

PRODUCTION FIGURES

Our closed 8.5 MW furnace has been an experimental furnace, and the emphasis has not been on production. During the 5 years period from 1977 to 81, we have developed a high temperature filter for handling the CO-rich off-gases, and a steam boiler for the firing of the uncleaned off-gases.

However, we have found it appropriate to show the following total operating time, as average per year in this period for the production of 75% FeSi in Table No. III.

Table No.III. Average per year operation on 75% FeSi in closed furnace

| Year | Operating time weeks | Power consumption KWh/ton | Average furnace load, MW | Operating time % |
|---|---|---|---|---|
| 1977 | 23 | 10,400 | 6.03 | 80.9 |
| 1978 | 34 | 10,739 | 7.17 | 87.0 |
| 1979 | 45 | 9,487 | 7.84 | 91.8 |
| 1980 | 34 | 9,969 | 9.49 | 80.4 |
| 1981 | 42 | 9,290 | 6.54 | 85.6 |

The Table III includes all necessary adjustment to the furnace operation, due to experimental work carried out on the closed furnace, our full scale high temperature filter from June 1979, and at the end of 1981 also the test work performed on the steam boiler as well as electrode breakages problems which occurred frequently before rebuilding.

To estimate the performance of the furnace, throughout the development period we have selected 8 consecutive weeks per year where little or no test-work was performed, which is shown in Table No. IV.

Table No. IV. Eight consecutive weeks per year with little of no test work producing 75% FeSi in closed furnace.

| Year | Week No. | 75% FeSi metric t/week | Power consumption KWh/metric ton | Average load, MW | Operating time % |
|---|---|---|---|---|---|
| 1977 | 43-50 | 100.8 | 9,758 | 6.461 | 87.3 |
| 1978 | 13-20 | 134.9 | 9,983 | 7.410 | 95.8 |
| 1979 | 2-9 | 156.4 | 8,738 | 8.488 | 95.7 |
| 1980 | 5-12 | 150.6 | 8,800 | 8.237 | 95.6 |
| 1981 | 22-29 | 142.5 | 8,296 | 7.850 | 93.83 |

The closed furnace was redesigned and rebuilt in the autumn of 1980, which incorporated a proper selection of non-magnetic material in certain areas of cover, and reduction of electrode length below contact clamps. These improvements seem to have reduced the power consumption with 500 KW per metric ton of tapped 75% FeSi.

The reduction in the electrode length below the contact clamps gave a marked improvement in the stability of the electrode behaviour.

Before the alteration any shut-down of the furnace with a duration beyond 2 hours would give electrode breakage in baked electrode. This could lead to a series of breaks and made furnace recovery very difficult and time consuming.

After rebuilding the electrode columns, electrode breakage has not occurred. Even after complete cool down of the electrodes it was possible to restart without experiencing any difficulties.

The consumption of quartz has been low due to the high silicon recovery in the closed furnace of 91-92 % against 85-87% when this furnace was operated as an open top furnace. (13)

As reported by Arnesen et al. (13) 10% reduction in carbon consumption has been found, and has been verified during 1981 operation together with the high silicon recovery. Based on this we have calculated variable operating cost for the furnace as when operated as an open furnace versus closed furnace operation. Table No. V shows a fairly conservative comparison, and converted from NOK to USD. 1 USD equals NOK 6.5.

Table No. V. Variable operating cost open versus closed 8.5 MW furnace producing 75% FeSi.

| Materials | Unit price USD/ton | Open furnace KWh/ton | Open furnace kg/ton | Open furnace USD/ton | Closed furnace KWh/ton | Closed furnace kg/ton | Closed furnace USD/ton |
|---|---|---|---|---|---|---|---|
| Quartz | 10.75 | | 1839 | 19.77 | | 1744 | 18.75 |
| Coke | 134.15 | | 693 | 92.97 | | 623 | 83.58 |
| Coal | 97.23 | | 479 | 46.57 | | 431 | 41.91 |
| Cost material | | | | 159.31 | | | 144.24 |
| Electrode paste | 369.23 | | 69 | 25.48 | | 83 | 30.46 |
| Electrical energy 15.4 mills per kwh | | 9,400 | | 144.77 | 8,900 | | 137.06 |
| Total variable operating cost | | | | 329.56 | | | 311.76 |

Metric tons of 75% FeSi = ton.

This gives in favour of the closed furnace USD 17.8 per metric ton of FeSi. An annual production on this 8.5 MW closed furnace of 8,000 metric tons will yield a saving of USD 142,400.

## ENERGY RECOVERY SYSTEMS

Energy recovery and cleaning of the gas from a closed 75% FeSi furnace are closely tied together. There are two methods of utilizing the combustible gas from the closed furnace:

- Clean the gas in a high temperature filter, and use the cleaned gas as fuel in a boiler, or use the cleaned gas for different chemical processes.

- Use the uncleaned gas as fuel in a specially designed boiler, and clean the flue-gases in a traditional manner.

The first method demands a high temperature filter developed by Elkem a/s. The HT-filter requires a high degree of instrumentation since the unit handles unburned gases with inherent explosion hazard and poisoning. The cleaned gas can be burned in a regular boiler.

The second method demands a special design boiler, but the flue-gases from the boiler can be cleaned in a standard Bag House filter.

To point out the advantage of the energy recovery system from a closed ferrosilicon furnace, we have to compare this system to the best known alternative today, the semi-open furnace.

In order to satisfy the imposed environmental requirement the exit gas from open, semi-open or closed furnaces must be filtered.

The temperature of the gas leaving the semi-open furnace is approx. 600°C and far too high for any filter. Three methods for temperature reduction are available:

- Dilution with air, which will increase the volume (about 10 $m^3N/KWh$) and increase filter cost (7)

- Using a waste heat boiler for temperature reduction, which will decrease the volume (about $3m^3N/KWh$), and decrease filter cost (6, 7)

- Using air cooled U-tube coolers, which will decrease the volume (about 6 $m^3N/KWh$ and reduce filter cost (7)

As the temperature of the off-gases leaving the semi-open furnace or entering a waste heat boiler depends on the amount of air dilution, likewise the boiler efficiency depends upon inlet gas temperature, this dependency is visulized in Fig. No.2 based upon the same amount of available energy.

A comparison of the gas flow for semi-open and closed 25 MW furnace is shown in Fig.No. 3.

Typical for the closed furnace is the very low amount of gas leaving the furnace. When the furnace is sealed no combustion takes place above the charge and the gas leaving the furnace is combustible.

The initial conditions for energy recovery are therefore at a maximum. The gas can be burned in a boiler and the excess air required for combustion can be controlled and adjusted to a minimum.

The total energy content of the gas from the closed furnace is lower compared with the semi-open furnace. This is an effect of lower consumption of fixed carbon in the closed furnace as described earlier in this paper.

## GAS AND DUST ANALYSIS FOR THE CLOSED 75% FeSi FURNACE

The gas production from the closed 75% FeSi furnace is approximately 0.23 $m^3N/KWh$ and the normal temperature range on the gas available for energy recovery is 200 - 400°C. Analysis of the gas are shown in Table No.VI.

Table No.VI Chemical analysis of gas from closed 75% FeSi furnace (Dry basis)

| | RANGE % | AVERAGE % |
|---|---|---|
| CO............. | 60-75 | 70 |
| $H_2$............. | 15-25 | 20 |
| $CO_2$............. | 2-5 | 3 |
| $O_2$............. | Below 0.5 | Below 0.5 |
| $N_2$............. | 3-10 | 4 |
| $CH_4$............. | 1.5-2.5 | 2 |
| CmHn............. | | 0.3 |
| $H_2O$............. | 7-10 | 8 |
| $H_2S$............ | 600-1200 ppm | 1000 ppm |

The calorific value of the gas is approximately 11,500 $kJ/m^3N$ gas (2,750 $Kcal/m^3N$ gas).

The dust concentration in the gas from a closed furnace is very high compared with open or semi-open furnaces and on average about 110 g/m3N.

Chemical analyses of the silica dust from a number of samples are shown on Table No. VII

Table No.VII. Analysis of 36 dust samples from closed 75% FeSi operation compared with dust from open furnace operation.

| | $SiO_2$ | Si (met) | C (tot) | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2$ | Ignition loss |
|---|---|---|---|---|---|---|---|---|---|---|
| Open furnace operation | 86-90 | | 0.8-2.3 | 0.3-5.0 | 0.2-1.7 | 0.2-0.5 | 1.0-3.5 | 0.3-1.8 | 0.5-3.5 | 2.0-4.0 |
| Closed furnace operation (average) | 80.3 | 0.25 | 9.3 | 1.31 | 0.44 | 0.22 | 1.34 | 0.65 | 1.19 | 8.3 |

The main difference between these findings is that the carbon content in the gas for a closed furnace is much higher than normal for open or semi-open furnace operation. The volume weight of the dust is low, roughly 1/3 of the volume weight of silica dust from normal open or semi-open furnace.

The dust from the closed furnace is estimated to have a specific surface from 20 - 28$m^2$ per gram whereas the dust from an open or semi-open furnace is about 20 - 22 $m^2$ per gram. Analysis of three samples for polycylic aromatic hydrocarbons (PAH) showed that the content varied from 2,500 to 6,500 ppm.

## ELKEM HIGH-TEMPERATURE FILTER

A need for a gas cleaning system based on a dry cleaning process for off-gases from the closed ferroalloy furnaces has been revealed as a future demand with regard to pollution requirements and optimal waste and energy conservation.

Until a few years ago the wet cleaning (4) was predominant for unburnt gases from the ferroalloy industry. The operating principle for the scrubber is simple, but the system has several draw-backs which will become more significant in the future:

- The water vapor in the scrubber gas entails heat losses after combustion.
- Non-recovered cooling of high temperature energy in the gas.
- Deposition restrictions of sludge with undesired substances.
- Utilization of particle discharge is more intricate in the form of sludge.

The development of a High Temperature Filter (HT-filter) was started in January 1976 and pilot filter tests were run on unburnt gas from FeMn, SiMn and FeSi processes with several filter materials. In June 1979 a full scale filter was connected to the closed 8.5 MW 75% FeSi furnace at Elkem a/s, Bremanger Smelteverk in Norway. The testing of filter materials and components has continued up till now and the filter system has proved safe and reliable.

## DESCRIPTION OF THE FILTER SYSTEM

A principle sketch of the system is outlined on Fig. Nos.4 and 5.

Raw Gas System:

The furnace gas is piped to the HT-filter via the gas offtake, one cyclone and raw gas fan.

The purpose of the cyclone is to cool the hot gas before entering the raw gas fan and to reduce the actual gas volume before entering the filter. It also separate any coarse particles to avoid excessive wear on the fan impeller.

The raw gas fan transports the gas and increases the pressure throughout the system to avoid underpressure to prevent air leaks into the filter system. Excess overpressure should also be avoided due to possible gas leaks to the furnace building. It must be kept in mind that the process gas from a closed furnace is both explosive and very poisonous.

A by-pass line connects the raw and clean gas side of the filter system. It is a substitute or if desirable supplement to the raw gas stack.

Filter Chambers:

Each filter chamber contains about 80 filter elements. The filter material best suited for the process has so far proved to be Inconel in the form of fiber cloth or sintered metal.

Clean Gas System:

The clean gas fan creates the necessary pressure drop across the filter material. The furnace pressure is controlled by the valve after the clean gas fan. The valve is a combined regulating and isolating valve which together with the inlet valve isolates the system from the furnace gas when desired.

Reverse Flow System:

Clean gas is used for cleaning the filter elements. Three gas fans pressurize a reverse flow tank for pulse cleaning of the elements.

Dust Transportation Systems:

The separated dust is fed by gravity into a chain conveyor which transports the dust to the hopper. The dust discharge pump initiated by level indicators in the hopper pushes the dust out of the system. The discharge pump is leak proof in such a way that no gas escapes and no air enters the system.

Dust Treatment:

Before dust deposition undesired elements in the dust have to be destroyed. A simple destruction process is under development by Elkem.

Silica dust from the FeSi-process is an increasingly valuable material to other industries. Methods for treatment of the discharge dust from the HT-filter to a high quality product is therefore under development.

## SAFETY PRECAUTIONS:

Explosion hazards exist should air enter the suction side of the filter system. Oxygen analyser is thus used for control. Should an explosion hazard arise, neutral gas from stand-by supply is purged into the filter system.

Poison or explosion hazards in the ambient air created by gas leaks to the atmosphere are controlled by CO-detectors located in the filter building.

## FILTER DESIGN

Design data for a HT filter for a 25 MW FeSi furnace are given in Table No.VIII.

Table No. VIII Elkem HT filter capacity 6.500 $m^3N/h$ (5 chambers)

| | |
|---|---|
| Filter Capacity per Chamber: | 1300 $m^3N/h$ |
| Design temperatur: | Max. 500°C. |
| Filter Inlet Gas Temperature: | 200 - 350°C |
| Filter Resistance: | 45 - 55 Pa/m/h |
| Gas Velocity through Filter Material: | 45 - 55 m/h |
| Power Consumption: | 80 kW |
| Dimension of Filter Chamber: | Dia. 2 m x Height 4 m |
| Dimension of Filter Building: | Length 10 m x Width 7 m x Height 12 m |

An economical comparison between the HT-filter and a standard wet gas scrubber with water treatment plant will show the following :

- Capital cost: 20 % less for the HT-filter
- Operating cost: Power consumption, operating and maintenance costs are less for the HT-filter.

ENERGY AND WASTE RECOVERY

1. Energy recovery of process gas:
   Combustion energy value from the 75 % FeSi process:
   3.2 kWh/$m^3$N.

   Sensible heat energy in gas with temperature 250°C:
   0.1 kWh/$m^3$N

   Energy loss after combustion due to heating of saturated water (30% by volume) in gas from a standard wet scrubber:
   0,6 kWh/$m^3$N.

   For a 25 MW closed FeSi-furnace the energy potential in the process gas is about 17 MW.

STEAM BOILER FOR UNCLEANED OFF-GASES

To use the uncleaned gas as fuel in a boiler special care must be taken due to the high dust concentration.

A functional test started in 1979 of a small hot-oil boiler with an energy input of 830 kW.

The results from this pilot boiler indicated that it was possible to burn the uncleaned gas without clogging of dust on the boiler heating surfaces. The test showed that special care had to be taken in the design of the gas transport system, the burner and of the boiler combustion chamber.

In 1980 our company established a cooperation agreement with Gøtaverken Ångteknik AB, Division Maskinverken (GVÅ) in Sweden for waste heat boilers for semi-open ferroalloy furnaces.

Together with GVÅ our company made a new design for a natural circulating water tube boiler specially designed for the purpose of burning uncleaned CO-gas from the closed 75% FeSi furnace at ELKEM a/s, Bremanger Smelteverk.

The boiler was designed for an energy input effect of 3 MW, but should cope with a maximum load of 4.5 MW. The design figures are shown in Table No. IX.

Table No.IX. The design figures for the boiler using uncleaned gas as fuel.

| Operation | Normal | Max. |
|---|---|---|
| Gas flow [$m3_{N/h}$] | 1000 | 1500 |
| Excess air ratio [%] | 20 | 20 |
| Flue-gas temp. [°C] | 360 | 540 |
| Steam flow [metric tons/h] | 3.3 | 4.3 |
| Steam temp. [°C] | 380 | 455 |
| Steam pressure [bar] | 18 | 18 |
| Feed water temp. [°C] | 100 | 100 |

The project started January 1981 and the functional test work on the boiler started November 1981. Complete boiler installation started middle of November 1981.

## BOILER DESIGN

A schematic drawing of the boiler system burning uncleaned gas from the closed furnace is shown in Fig. No.6.

The uncleaned gas is transported from the furnace stack through a specially designed, isolated pipeline, 80 meters long, to the boiler gas burner.

The transport system is equipped with its own raw gas stack serving as a safety relief of the gas in case of an unexpected shut down of the boiler.

Since the transport system handles uncleaned gas with inherent explosion hazards, we developed a safety system in corporation with the National Inspectorate for Explosives and Flamables.

To ignite the mixture of uncleaned gas and air, the boiler is equipped with smaller igniter using propane gas as fuel.

The propane as burner has an input effect of about 220kW.

As shown in Fig.6 the gas burner is placed at the top of the combustion chamber.

The bottom of the combustion chamber is equipped with a continuous screw conveyor removing the precipitated dust.

The super heater and economiser surfaces are placed in last passage of the boiler. The heating surfaces are cleaned by means of shoot-cleaning.

To reduce the costs of the boiler the exit gas temperature is very high as shown in Table No.X. The standard Bag House filter design temperature is lower than boiler exit temperature. Therefore, the exhaust gas had to be diluted to reach acceptable temperature conditions.

The superheated steam produced by the boiler is reduced in pressure and temperature before entering the condenser. The condensate is pumped back to the boiler by a circulation pump.

The project intention was as follows:

- To observe the behaviour of dust in the transport system, the gas burner, in the combustion chamber and on the heating surfaces.

- To measure the efficiency of the boiler during different operating condition.

- To measure and analyse the dust and gas leaving the boiler.

## EXPERIENCE AND RESULTS FROM THE OPERATION

The first test of the boiler using uncleaned gas as fuel was carried out during the period November - December 1981.

The results of this test showed that the special care which has been taken in the design of the boiler was a success.

The test was carried out with different inputs and different excess air ratio.

Table No.X shows the results from three different operations of the boiler. In the last campaign the shoot-cleaning device was not used and this resulted in a lower degree of superheat as seen in Table No.X.

Table No.X. Results from three different operation conditions for the boiler using uncleaned gass as fuel.

| Operation No. | 1 | 2 | 3 |
|---|---|---|---|
| Gas flow [$mn^3/h$] | 850 | 1000 | 1250 |
| Gas temp. [°C] | 180 | 187 | 219 |
| Excess air [$mn^3/h$] | 2675 | 3400 | 3750 |
| Excess air ratio [%] | 41 | 52 | 35 |
| Flue-gas temp. [°C] | 340 | 375 | 380 |
| Steam flow [tons/h] | 3.0 | 3.6 | 4.3 |
| Steam pressure [bar] | 18 | 17.5 | 17.5 |
| Steam temp. [°C] | 370 | 390 | 370 |
| Feedwater temp. [°C] | 98 | 99 | 103 |
| Boiler efficiency [%] | 81 | 78 | 81 |

The efficienty of the boiler was higher than expected due to less dust layer on the heating surfaces. As shown on Table No. X the boiler efficiency was 78% to 81%, depending on the excess air ratio, even though the exhaust gas temperature was about 380°C.

With an exhaust gas temperature of normally 180°C, the boiler efficiency will increase to 89%.

During the test period samples of the dust were drawn in order to determine chemical analysis and physical properties.

Analysis of the dust for carbon showed that the content was decreased to an average of 2.5%.

The volume weight of the dust was increased to an average of 300 grams per liter, compared with an average of 70 grams per liter for the dust from the furnace.

As the dust passes through the boiler, the specific surface reduces to 1/10.

Analysis for polycylic aromatic hydrocarbons (PAH) shows that the content is reduced to less than 100 ppm.

Due to the high temperature in the combustion chamber some of the amorphous dust changes to crystalline dust. Most of the crystalline dust was unloaded at the bottom of the combustion chamber of the boiler.

## CONCLUSION

The development work Elkem started nearly ten years ago has opened the door for a more efficient ferrosilicon process.

This is based on the following major achievement in improving the smelting technology through

- The Split Furnace Concept
- The Closed FeSi Furnace
- The High Temperature Filter
- The Steam Boiler for uncleaned CO gas.

What does this actually mean for a future smelting plant taking advantage of this new technology?

To enable us to make a just comparison it would be correct to look at a greenfield plant and imagine the evaluation of a semi-open and closed furnace with a capacity of 25 MW producing 75% FeSi for the following alternatives:

A - Semi-open furnace with waste heat boiler and Bag House filter.

B - Closed furnace with HT-filter and standard steam boiler.
C - Closed furnace with steam boiler for unclean gas and Bag House filter.

To illustrate in a simple manner the potential of capital saving we have selected the base of 100 for alternative C, the closed furnace with steam boiler for uncleaned gas and Bag House filter, which is shown in Table No.XI.

Table No. XI. Cost comparison for a 25 MW, 75% FeSi furnace in 3 alternatives.

| | Alternative | | |
|---|---|---|---|
| Equipment | A. | B. | C. |
| One complete furnace installation, incl. building | 100 | 100 | 100 |
| Filter installation | 570 | 230 | 100 |
| Energy recovery system | 140 | 72 | 100 |
| Total installation cost | 115 | 100 | 100 |

Earlier in this paper we have shown that for one 8.5 MW closed furnace the variable cost for this furnace compared with open top operation yields a saving of about 5%. It should be reasonable to assume that a 25 MW closed furnace would show a similar saving of 4-5%.

A study of the maintenance cost on the open top and closed furnace shows an improvment due to less heat exposure to the equipment.

Saving energy is also conserving energy. Comparing the total energy requirement to operate the three plant alternatives above would show, using 100 as a base for alternative C. the following relationship in Table No. XII.

Table No.XII Total energy requirement for a 25 MW 75% FeSi plant in 3 alternatives.

| | |
|---|---|
| Semi-open furnace with waste heat boiler and Bag House filter | 103 |
| Closed furnace with HT filter and standard boiler | 100 |
| Closed furnace with boiler for uncleaned gas and Bag House filter | 100 |

It would not be possible here to delve deeper into the new aspects which have been opened up for the ferrosilicon process. We will just conclude with the statement that we stand on the threshold of a new technology which has the potential in energy conservation for an energy consuming process.

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14) Tveit, Bjørn and Gard, Eilif
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15) Schei, Anders
"A Stoichiomatric Model of the Ferrosilicon Process".
Presented at the Iron and Steel Society of AIME, the 39th Electric Furnace Conference in Houston, December 9-11, 1981.

16) Aase, Even Per
"Electric reduction Furnace for High Grade Ferro-Silicon and Silicon Metal with Energy Recovery Systems".
Presented at the exhibition Elektro -82 in Moscow, July 26, 1982.

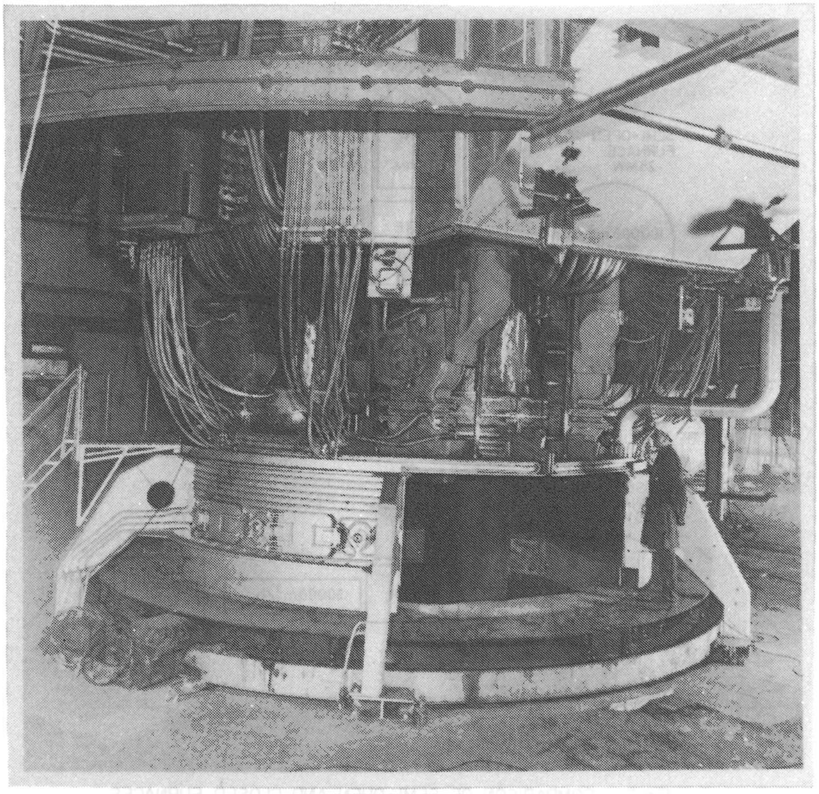

Fig.1 THE 8,5 MW CLOSED FERROSILICON FURNACE AT ELKEM A/s, BREMANGER SMELTEVERK. (ONE SECTION OF COVER REMOVED.)

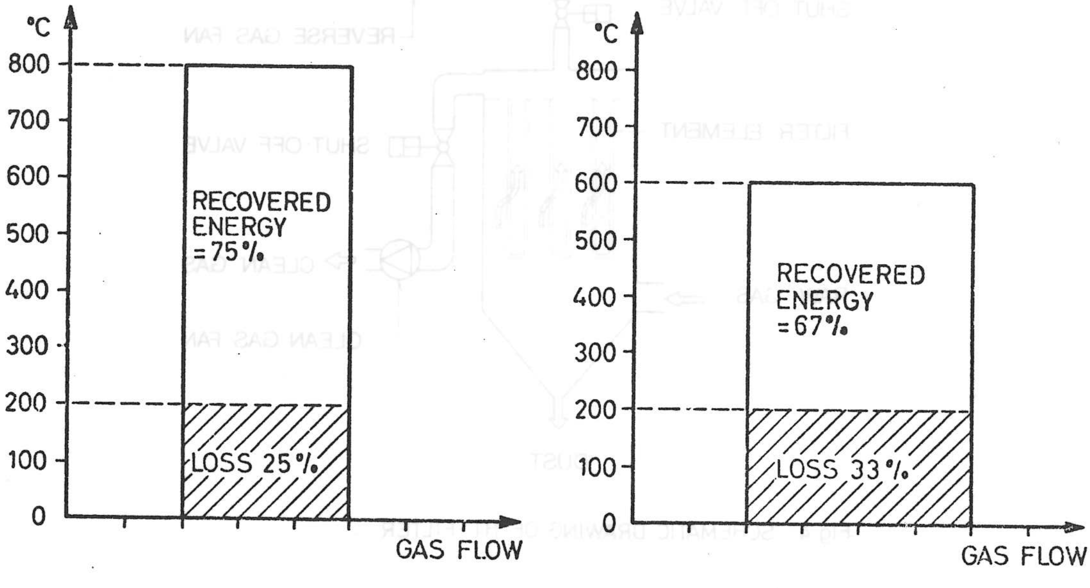


Fig. 2 THE WASTE HEAT BOILER EFFICIENCY FOR TWO DIFFERENT INLET GAS TEMPERATURES AND EQUAL AVAILABLE ENERGY.

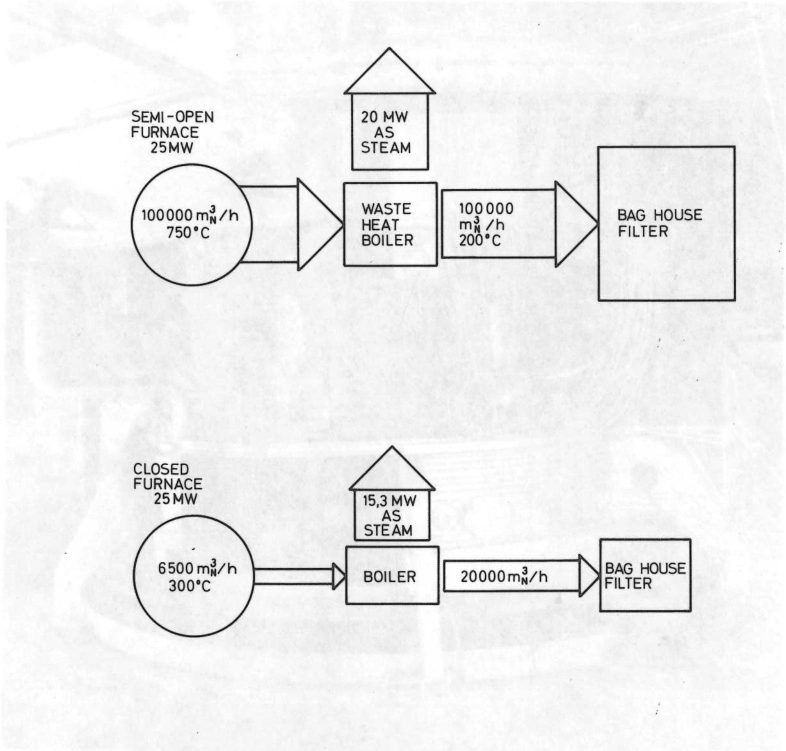


Fig.3 COMPARISON OF SEMI-OPEN AND CLOSED FURNACES FOR 75% FeSi WITH ENERGY RECOVERY.

ELKEM HIGH TEMPERATURE FILTER

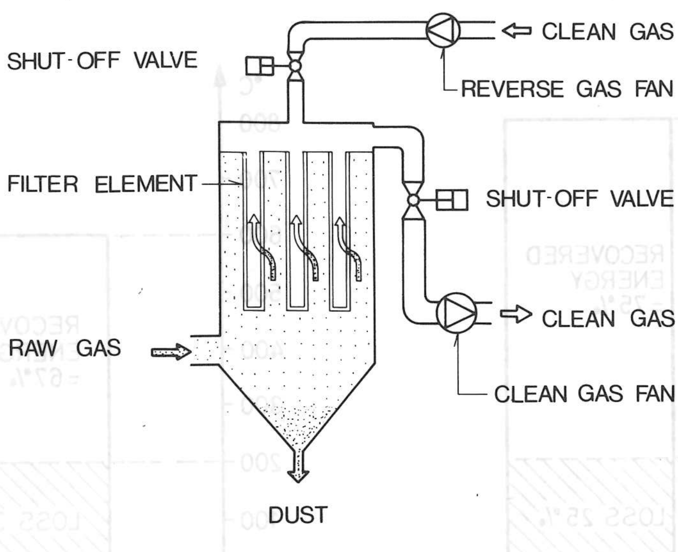


Fig.4 SCHEMATIC DRAWING OF HT-FILTER.

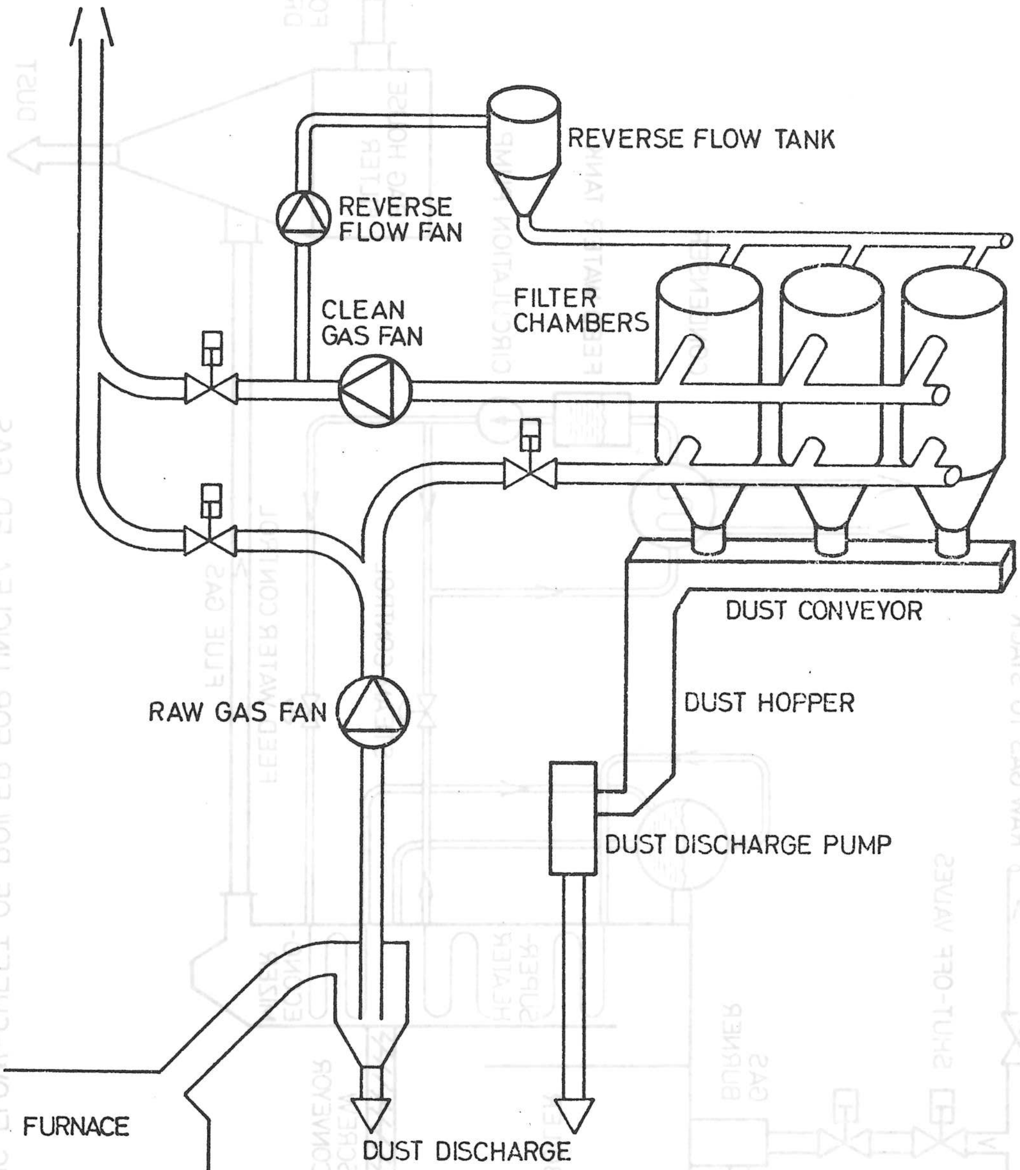


Fig.5 HIGH TEMPERATURE FILTER.

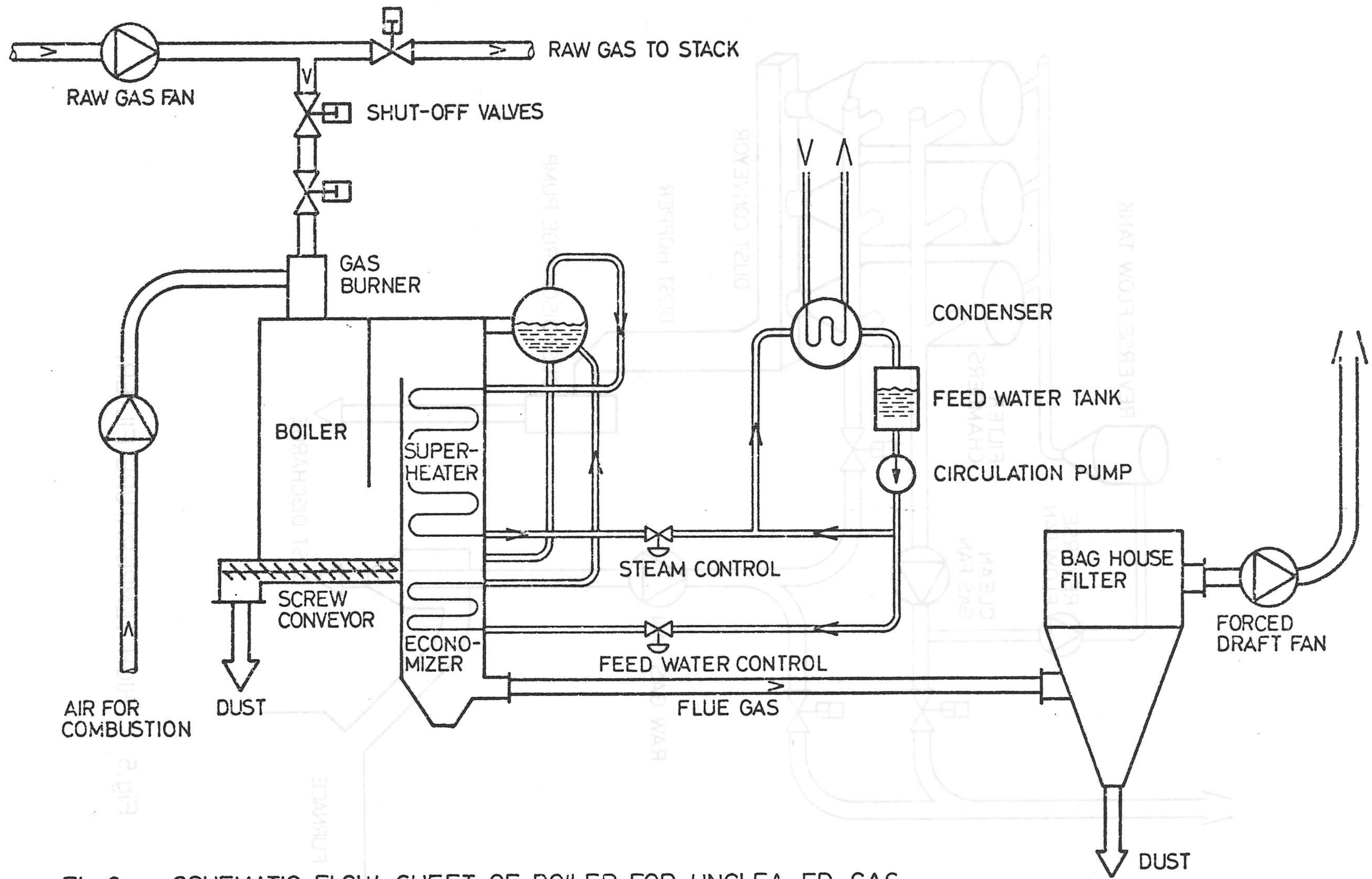


Fig.6 SCHEMATIC FLOW-SHEET OF BOILER FOR UNCLEA ED GAS.