DEVELOPMENT AND CURRENT STATUS OF THE COREX® PROCESS WITH SPECIAL FOCUS ON COREX BAOSTEEL[1]

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Abstract
With the start-up of the COREX® C-3000 plant with an annual capacity of 1.5 million t hot metal by Baosteel, China, a new milestone for the COREX technology could be reached. This module represents the up-scaling and the experiences made with the COREX plants in operation at Mittal Steel South Africa, at Jindal, India and the two FINEX® plants at Posco, Korea. Considerable changes in the raw material sector (iron ores, price of coke, coking coal and steam coal, etc.) and the general increase of energy cost (natural gas, electric power, etc.) in combination with the positive experiences during the operation and strictly enforced environmental laws make it worth today to carefully evaluate the COREX technology in comparison with the traditional blast furnace technology. In addition to the first COREX Plant C-3000 in operation, Baosteel signed the contract for the second COREX Plant C-3000 in December 2007. Main focus of this presentation is laid on developments of the COREX technology, giving inside views about the operating COREX plants at Mittal Steel South Africa, Jindal South West Steel, especially the COREX plant C-3000 of Baosteel, the COREX plants under construction (Essar Steel), new technological developments and factors endeavouring the COREX technology.
Key words: COREX; Reduction; New process

DESENVOLVIMENTO E ATUAL STATUS DO PROCESSO COREX® COM FOCO NA COREX BAOSTEEL

Resumo
Com o início da operação da planta COREX® C-3000 com capacidade de produção de 1,5 milhões de toneladas na Baosteel, China, a tecnologia COREX atingiu um novo marco. Tal módulo representa um aumento de escala e as experiências feitas com as plantas COREX em operação na Mittal Steel África do Sul, na Jindal, Índia, e com as duas plantas FINEX em Posco, Coréia. Mudanças consideráveis com relação a matérias-primas (minério de ferro, preço do coque e carvão, etc.) e o aumento nos custos de energia (gás natural, energia elétrica, etc.), somados às boas experiências de operação e à rigorosidade das leis ambientais tornam válida a avaliação cuidadosa da tecnologia COREX em comparação com a tradicional tecnologia de altos-fornos. Adicionalmente a primeira Planta COREX C-3000, em dezembro de 2007, a Baosteel assinou um contrato para a instalação da segunda planta COREX C-3000. Este trabalho possui foco na apresentação do desenvolvimento da tecnologia COREX, mostrando as plantas da Mittal Steel South Africa, Jindal South West Steel, especialmente a planta C-3000 da Baosteel, e as plantas COREX em construção (Essar Steel), e desenvolvimentos de novas tecnologias envolvendo a tecnologia COREX.
Palavras-chave: COREX; Redução; Novos processos.

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1 INTRODUCTION

The successful operation of the COREX plants in India, South Africa and Korea has confirmed that the COREX Process is a proven economical and environmentally-friendly alternative to the conventional blast furnace technology. With the successful start-up of the first COREX C-3000 plant with an annual capacity of 1.5 million tons of hot metal at Baosteel, China, a new milestone has been reached for the COREX technology. This up-scaled module is based the experiences made with the COREX plants currently in operation and the latest development results.

Siemens VAI and all COREX plant operators are still continuously working to increase productivity, to introduce alternative low-cost raw materials, to gain operation experience, and to use state-of-the-art concepts for the COREX export gas. The achievements are quite considerable when compared to the matured blast furnace route and will contribute to further enhancing this technology.

Currently four COREX plants are in operation (1 x C-2000 Plant at Mittal Steel South Africa/South Africa, 2 x C-2000 Plants at Jindal South West Steel/India and 1 x C-3000 Plants at Baosteel). In addition, the two COREX C-2000 plants are presently being relocated from Hanbo, Korea, to Essar Steel, India and one further COREX C-3000 plant is under construction at Baosteel/China – these plants will further add valuable information to the large COREX experience pool.

In addition, changes in the raw material sector (price of coke, coking coal and steam coal, etc.) and the general increase of energy costs (natural gas, electric power, etc.) make it even more worthwhile to carefully evaluate the COREX technology in comparison with the blast furnace technology.

Currently, an increased interest in the COREX and FINEX technology can be seen as a result of a number of factors which have been confirmed during the past years:

- Successful start-up of the COREX C-3000 plant at Baosteel November 8th, 2007 and of the FINEX 1.5M Plant at POSCO on April 11, 2007
- The COREX and FINEX plants, still the only industrially acknowledged alternative to the blast furnace route, operate above nominal capacity, at high availabilities and produce high-quality hot metal at low consumption rates.
- As a consequence of the improved operation, plant feasibility has increased considerably.
- The results of production-cost calculations have been verified under operational practice.
- At the FINEX demonstration plant and the FINEX 1.5M plant of POSCO major operational improvements e.g. reduction of coal and oxygen consumption have been achieved. These improvements can also be fully used in the COREX technology.
- New concepts for the brown field implementation of a COREX or FINEX plant are available

In addition to process and technology related improvements, other “external” factors, driven by the global development in the iron and steel industry, support the COREX and FINEX technology:

- In most countries environmental-protection measures have gained more importance and strict legislative regulations for limitations of emissions have been implemented.

- Due to the lower availability of metallurgical coal and due to higher steel consumption in the booming countries, e.g. China and India, the price of metallurgical coal has increased considerably in comparison with "COREX/FINEX" coal. As the global reserves of "low-cost-mining metallurgical coal" are being increasingly depleted, a significant price increase is expected for this type of coal in the future. The gap for the price difference between metallurgical coal and “COREX/FINEX” coals has widened up.
- Coke price currently peaks at astronomical heights due to lower coke exports ex China (Figure 1)
- Another highly important factor is the continuing price increase for energies, especially for natural gas (Figure 2). Since a COREX plant produces higher quantities of a clean gas which can be used as a substitute to natural gas, this technology is extremely attractive in areas where a high natural gas price prevails. Due to the recycling of top gas of the FINEX plant, the value of the export gas credit will be lower
- The comparable CO_2 emission of a COREX/FINEX plant/power plant combination in one of the booming countries is considerably lower than the alternative blast furnace route/power plant combination considering an equal amount of hot metal and electric power produced. Currently two CO_2 certificate trading projects (CDM-projects) with COREX – one at JSW and one at Baosteel are in place

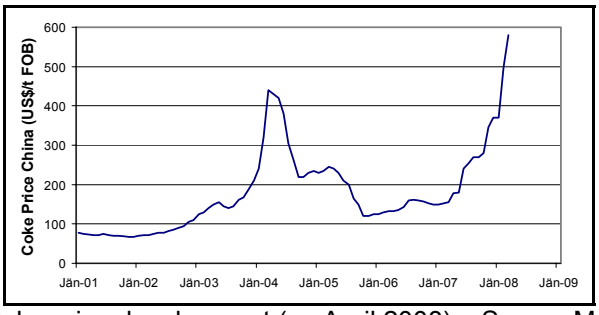

Figure 1. Coke price development (as April 2008) – Source Metal Bulletin

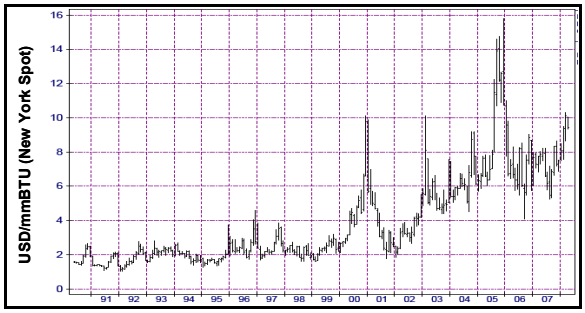

Figure 2. Natural gas price development (as of April 2008) – source: www.mrci.com

2 DEVELOPMENT OF THE COREX/FINEX PROCESS

COREX and FINEX are the world's only industrially proven smelting reduction processes which allow for the cost-efficient and environmentally friendly production of hot metal from from all available iron sources i.e. lump ore, pellets and sinter feed fine ore without the need for coke or coking plants. Figure 3 shows the development of the COREX and FINEX process. The existing COREX plants have achieved production rates above the planned nominal capacity. Based on these operation

results and by optimizing the equipment, the capacity ranges of the modules have been increased and newly defined. Currently, the biggest COREX module size would produce 1.75 million t/a hot metal and the biggest FINEX plant 2 million tons of hot metal.

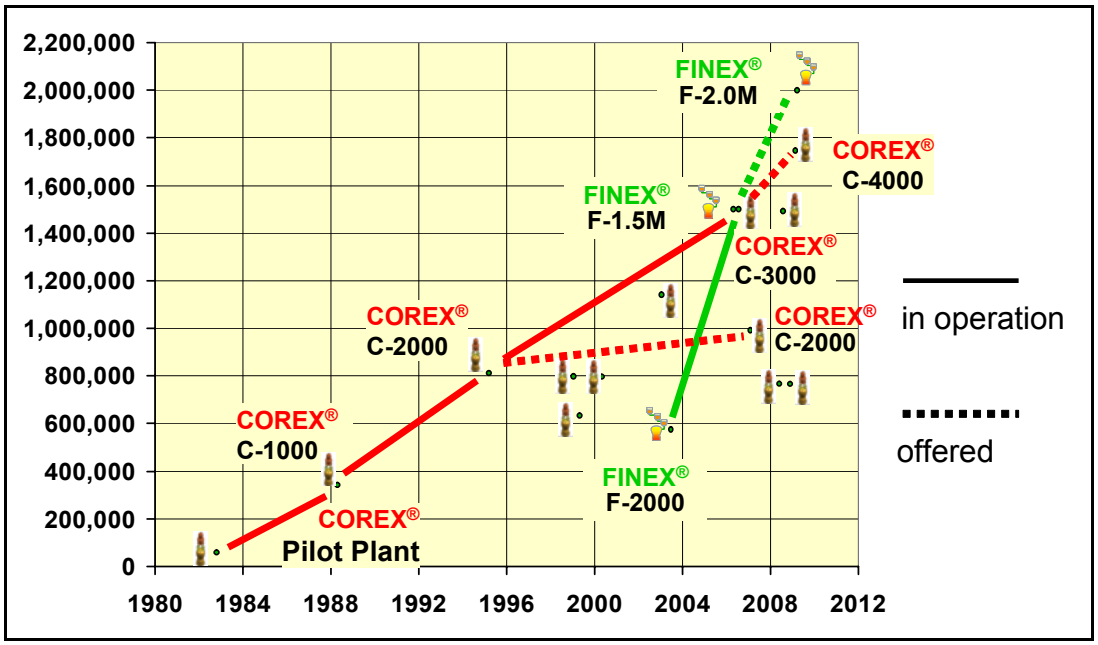

Figure 3. Capacity development of the COREX and FINEX process.

2.1 Status of Operating COREX Plants

Since the first industrial application of the COREX process, the COREX C-1000 plant of ISCOR Pretoria in South Africa, more than 30 million tons of hot metal have been produced via the COREX route (Figure 4).

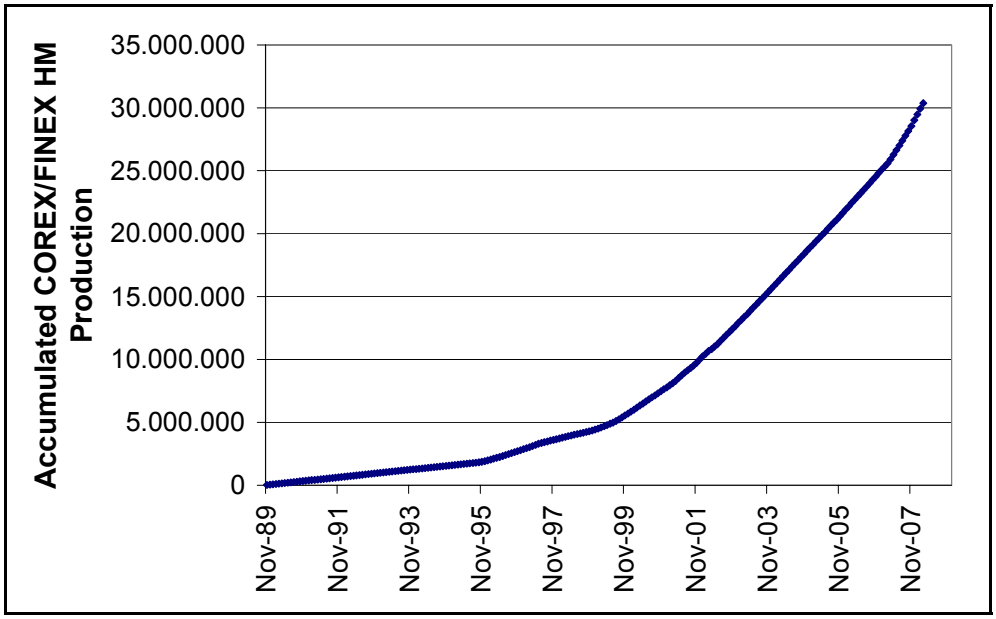

Figure 4. Accumulated COREX hot metal production.

2.1.1 COREX C-3000 Plants for Baosteel, China

Shanghai Baosteel Group Corp. (Baosteel), one of the largest steelmakers in China, contracted Siemens VAI for the installation of the world's first two modules of COREX C-3000 with an annual hot-metal capacity of 1.5 million tons each. These plants will be the basis for a new steel works currently under construction at Luojing on the western outskirts of Shanghai (Figure 5) where this steel works is subject to strict environmental regulations. The project duration for Module 01 lasted 30 months and it was put into operation on November 8th, 2007. Module 02 project is ready for construction start and it is expected to put it into operation in March of 2010 (Figure 6 and 7).

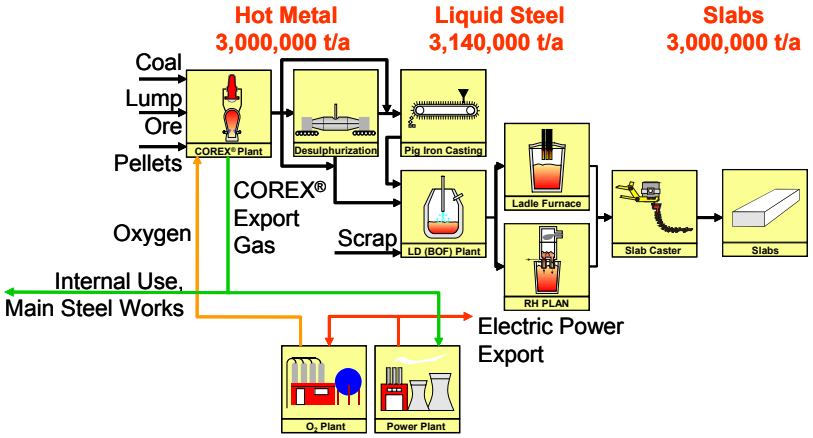

Figure 5. Planned production route of the Luojing steel plant–phase 2.

Figure 6. COREX Module 01.

Figure 7. First tap at the COREX Module 01 on November 8th, 2008.

The major reasons for the decision for the new COREX® plant are as follows:

- Economical production of hot metal — The production costs of the large blast furnaces at Baosteel's main works located in the vicinity of the new Luojing site were set by Baosteel as a benchmark.
- Environmentally friendly production of hot metal — Luojing site is an environmentally restricted area as part of the water supply for Shanghai is sourced from this area. It was clear that a blast furnace route would not receive the approval to be built in this area. Due to the proven environmental advantages of the COREX® process, the permission was granted.
- Use of 100% Chinese coals
- Lower dependency on the local power and natural-gas supply — The COREX® export gas is used for a new 150 MW_{el} combined-cycle power plant and for heating purposes within the Luojing Works and in the adjacent main steel works of Baosteel.
- Confirmation of Baosteel's role in China as a technological leader in ironmaking

First Operation Results

The Figure 8 shows the accumulated hot metal production.

After the initial ramp up of the plant the production reached a maximum of 170 t/h. Due to instability in the reduction shaft, an emptying of the shaft took place in end of March 2008. During emptying several modifications were carried out at the shaft and associated equipment. Currently the plant is operating at approx. 180 t/h achieving its nominal capacity. It is expected that the plant operations will further stabilize and operated a higher capacities during the next months. In the end of May 2008 the Final Acceptance Test (FAT) has been passed successfully.

Typical hot metal quality which is comparable to the blast furnace is shown in Table 1.

Table 1. Typical hot metal quality

Temperature	Carbon	Sulphur	Silicon
°C	%	%	%
1530	4.55	0.055	0.6

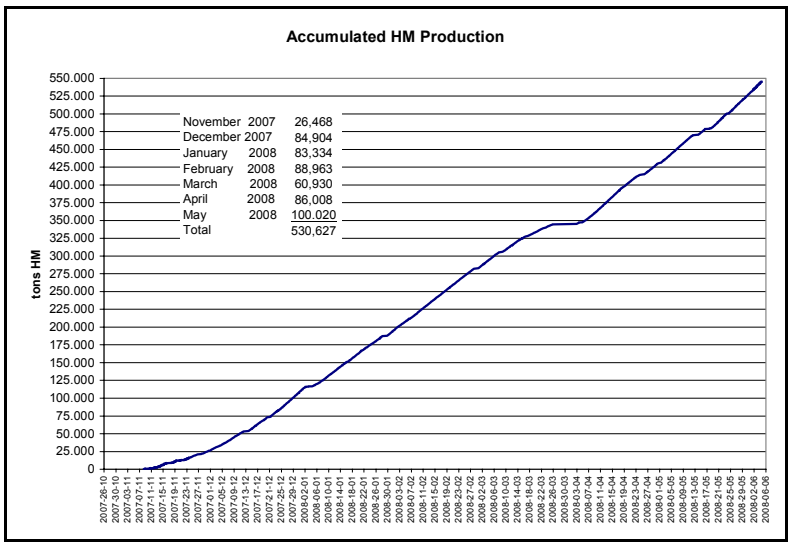

Figure 8. Accumulated hot metal production.

2.1.2 Relocation of two COREX C-2000 Plants from Asan Bay, Korea to Gujarat, India

In 1995/1996 Hanbo Steel, Korea started to build a steel plant at Asan Bay, Korea. Siemens VAI supplied two COREX C-2000 units connected to one Midrex DR plant. Before being put in operation, Hanbo Steel went bankrupt in 1996.

The plants have been bought by Essar Hazira Ltd., India, who is now relocating these plants from Asan Bay, Korea to the Hazira steel complex at Gujarat, India. There, the two COREX plants, the Midrex plant and a new blast furnace will form the ironmaking basis for a new steel mill for the annual production of 1.8 million t of slabs and 2 million t of long products. Siemens VAI will supply an update in engineering, automation and equipment, as well as advisory services for the plant start-up for the two COREX plants.

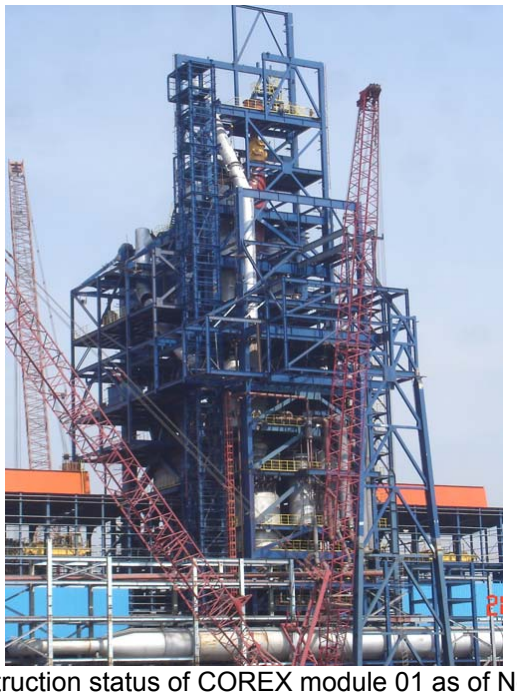

Figure 9. Construction status of COREX module 01 as of November 2007.

2.1.3 Operation of the two COREX C-2000 Plants at Jindal South West Steel (JSW), India [1]

The synergistic combination of COREX and blast furnace in respect to coal/coke shown schematically in Figure 10. The non-coking coal used in COREX is screened in the coal screening plant. The lump coal is fed to COREX and the coal fines (-6.3 mm) are fed to the blast furnace as pulverized coal injection (PCI) and also to the non-recovery coke oven (up to 20%). Further, out of the total coke produced, lump coke is fed to the blast furnace, nut coke (6 – 25 mm) to the COREX and coke breeze (-6.3 mm) to the sinter plant.

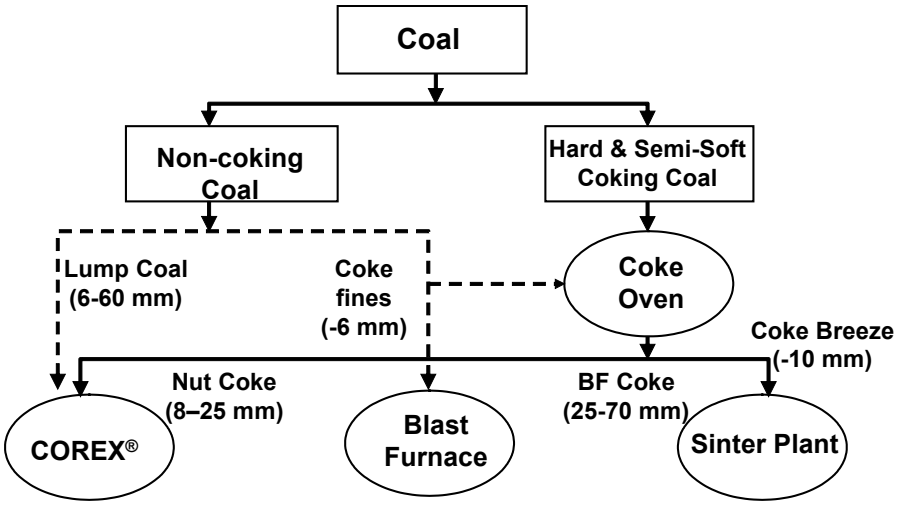

Figure 10. Use of Coal/Coke in the JSW Steel Works.

In addition, COREX export gas is used as back-up in blast furnace stoves, boilers, and in the sinter and pellet plant.

More than 70% of the plant wastes, such as COREX and BF sludge, limestone/dolomite fines, LD slag, etc. are recycled into COREX either directly or indirectly through the pellet/sinter plants. The synergy of COREX and blast furnace has helped JSW steel to maximize the utilization of solid waste and thereby reduced the cost of hot metal.

The availability of both the COREX® and blast furnace based on calendar hours over the last 3 years is shown in Figure 11. It can be observed that the availability has improved in both the units over the years due to various modifications. The availabilities of COREX and the blast furnace are similar whereas the COREX plant calls for slightly more maintenance due to the greater gas handling system. The start of the COREX plant is easier after a shutdown and the rated capacity can be reached in an hour.

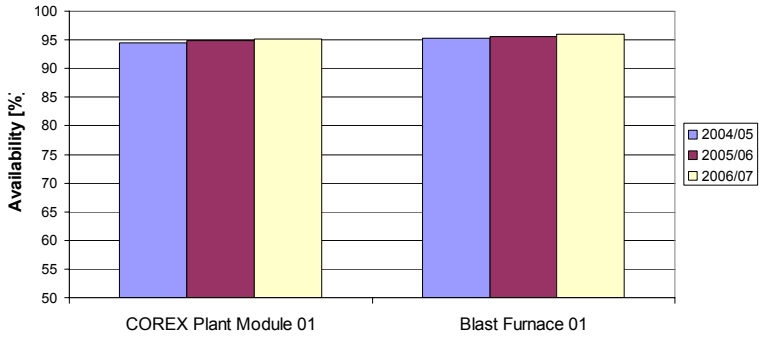

Figure 11. Availability Development of BF No. 1 and the COREX Module 01.

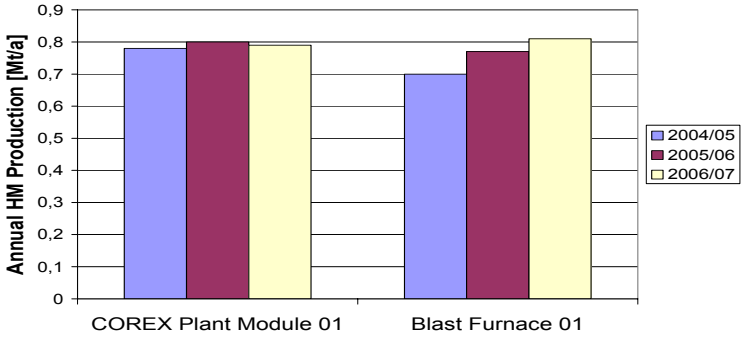

Figure 12. Capacity Development of BF No. 1 and the COREX Module 01.

3 CONCLUSIONS

Based on the successful experience of the four operating COREX plants, a considerable knowledge base has been accumulated with respect to engineering and operation. This knowledge and subsequent investigations have resulted in a most competitive hot-metal production compared with the blast-furnace route. During the past years, market conditions and “external” factors have also changed in favour of COREX technology, e.g. mandatory environmental legislation, increased costs for metallurgical coal compared with COREX coal and an increased energy price. Baosteel and Essar Steel selected the COREX technology for exactly these reasons: Economical and environmentally-friendly production of hot metal and lower dependency on metallurgical coal or externally sourced energies e.g. natural gas.

Developments and optimization of COREX are still underway and major additional economical and technological improvements are yet anticipated. Under consideration of the highly flexible plant concepts, well-proven components and systems, new process features and equipment as well as the highly competitive production costs, Siemens VAI is confident that the COREX process will capture an increasing share of the hot-metal production worldwide with its attractive module sizes (Figure 13).

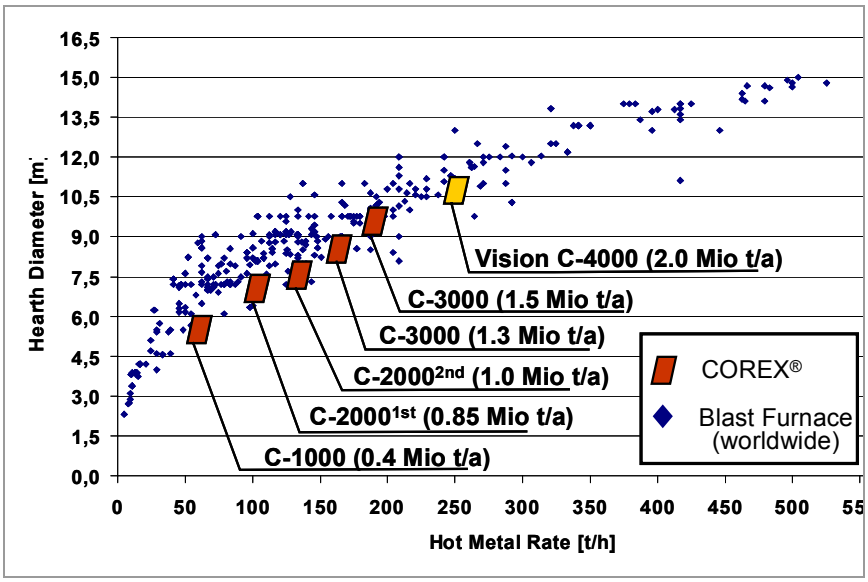

Figure 13. COREX module sizes available.

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