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PRIMETALS TECHNOLOGIES

THE FINEX® PROCESS

ECONOMICAL AND ENVIRONMENTALLY SAFE IRONMAKING

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IRONMAKING
AT LOWER COSTS AND EMISSIONS

YOUR CHALLENGE

Rising energy demand, continuous price increases for natural gas and raw materials, and steadily decreasing quality of iron ore due to the global resource depletion are formidable challenges today.

The conventional blast furnace route is too costly and energy-intensive to keep pace with dynamic market changes.

The requirements make it much more difficult to fulfil ever stricter environmental regulations and achieve sustainable economical competitiveness.

OUR SOLUTION

The FINEX® Process is jointly developed by POSCO, Korea and Primetals Technologies, Austria. Besides COREX®, FINEX® is the only commercial proven alternative iron making process to the blast furnace (BF) route, consisting of blast furnace, sinter plant and coke oven, generating hot metal.

FINEX® is based on the direct use of iron ore fines and non-coking coal and eliminates the coke-making and the sintering processes which are most critical to the conventional blast furnace process. Combining two decisive advantages leads to lower production costs and essential reduction of environmental emissions in comparison with the conventional blast furnace route.

The FINEX® Process combines coking plant, sinter plant and blast furnace into a single iron making unit.

ADVANTAGES OF THE FINEX® PROCESS:

- **Economic benefit -** Low investment and operational costs due to the elimination of coking and sinter plants
- **Ecological benefit -** Lowest process-related emission rates
- **Product quality -** Hot metal quality suitable for ecological steel applications
- **CO_2 mitigation potential -** by using pure oxygen
- **Resource preserving -** Uses directly a wide range of iron ores and non-coking coals
- **Beneficial by-products -** Generation of highly valuable export gas for various purposes (electric power generation, DRI production, or natural gas substitution)

THE FINEX® PROCESS

A COMMERCIALLY PROVEN ALTERNATIVE IRON MAKING PROCESS TO THE CONVENTIONAL BLAST FURNACE ROUTE

THE MAIN DIFFERENCES BETWEEN THE FINEX® PROCESS AND A CONVENTIONAL BLAST FURNACE ROUTE ARE

- Non-coking coal can be used directly as a reducing agent and energy source
- 100% fine ore can be directly charged to the process; no sintering or pelletising is required.
- Pure oxygen instead of nitrogen-rich hot blast is used

DIRECT USE OF NON-COKING COAL

Various non-coking coal types can be charged directly to the melter gasifier making a coking plant unnecessary. The high dome temperature exceeding 1,000 °C results in entire cracking of the coal's relieved hydrocarbons and avoiding the formation of tar.

DIRECT USE OF FINE IRON ORE

The typical iron oxide mix for FINEX® is hematite fine ore with a typical mean grain size of 1 to 2 mm. Operational results also proved stable operations with a magnetite pellet feed in a ratio of up to 30%.

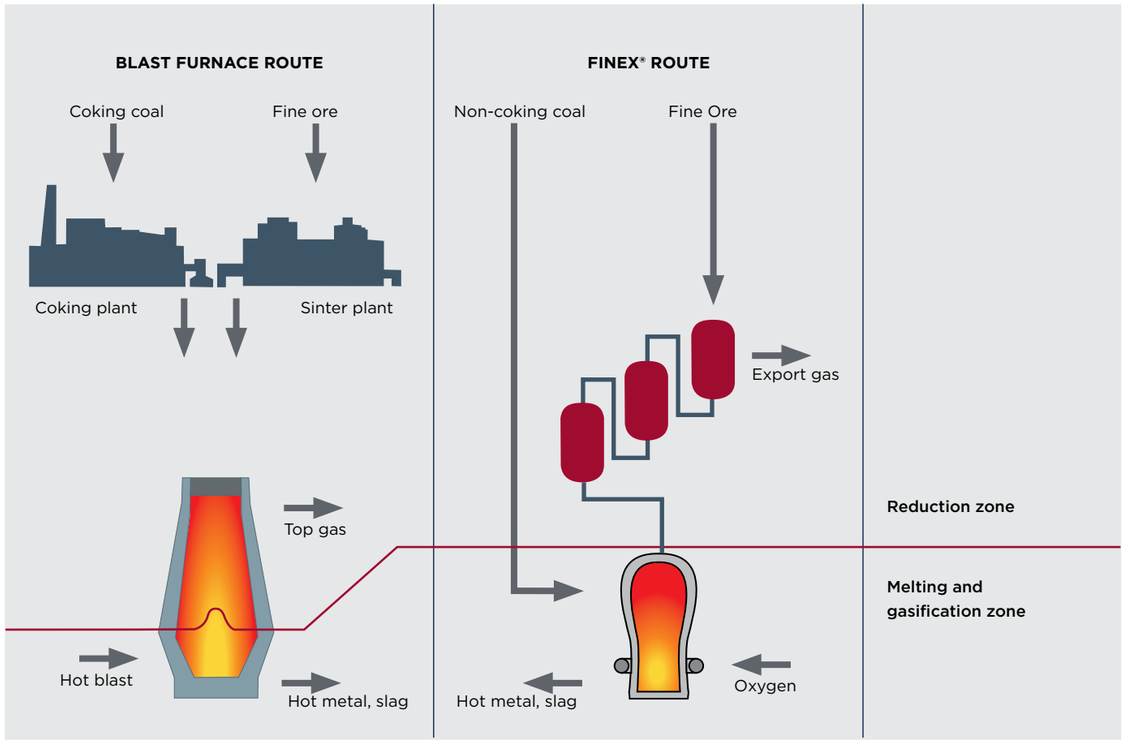
USE OF PURE OXYGEN

While blast furnace operators aim to enrich the hot blast with oxygen, the FINEX® Process already uses high-purity oxygen, resulting in an export gas with only low amounts of nitrogen. As its net calorific value is more than two times of the blast furnace top gas, it can be partially recycled for reduction work or used for heat or energy generation. Depending on the steelworks demand, additional value can be created with the produced gas.

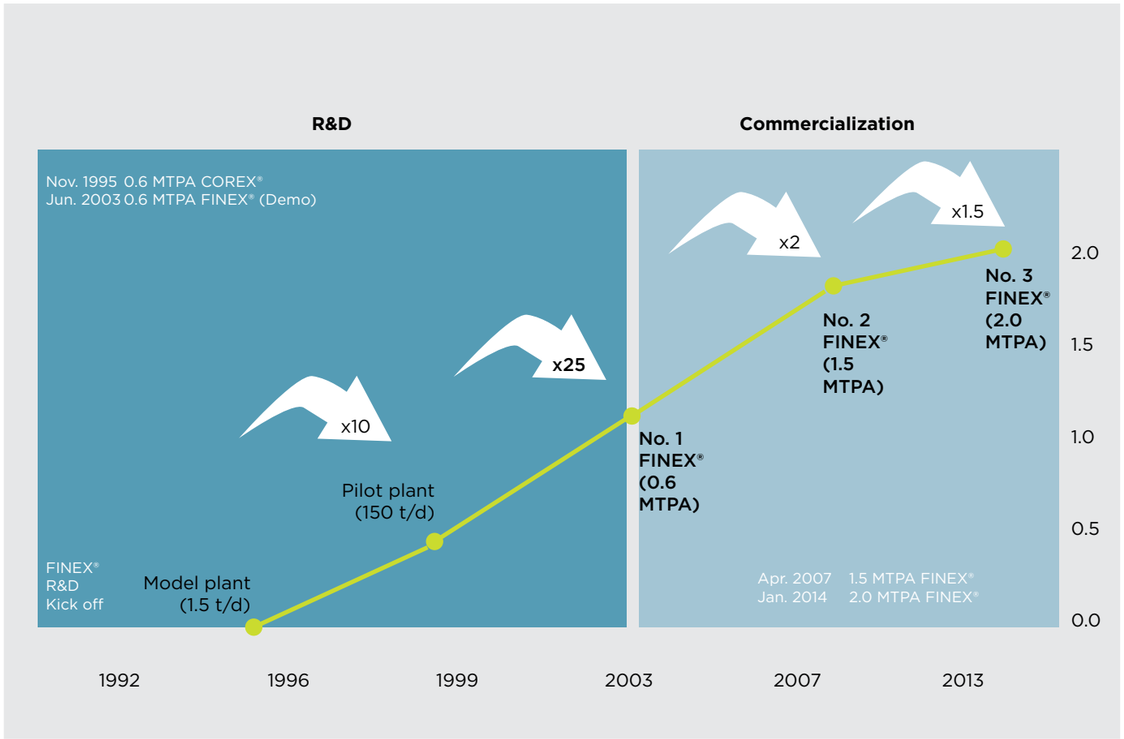
THE MILESTONES OF THE FINEX® PROCESS

In December 1992, POSCO and Primetals Technologies signed a cooperation agreement for the joint development of the FINEX® Process. Following initial laboratory, bench scale and pilot-plant tests, the FINEX® F-0.6M Demonstration Plant with a nominal capacity of 2000 t/d was built at Pohang, Korea, and started up in May 2003. On the basis of the successful results and following optimization of equipment and process parameters, POSCO decided to install the industrial FINEX® F-1.5M Plant (1.5 million t/a nominal production capacity).

POSCO broke the ground to build the first commercial FINEX® F-1.5M plant in August 2004. The plant has commenced operation in April 2007. Based on the successful results of the FINEX® F-1.5M plant POSCO and Primetals Technologies decided to develop the FINEX® F-2.0M plant with an annual hot metal capacity of 2 million t/a. In 2011 POSCO started to build the first FINEX® F-2.0M and the plant has been successfully put into operation in January 2014.



Process comparison - FINEX®/BF route



Milestones of the FINEX® Process

THE FINEX® PROCESS – A LOOK INSIDE
EFFICIENCY AT WORK

PROCESS DESCRIPTION

The FINEX® smelting-reduction process is perhaps the most exciting ironmaking technology on the market. It is distinguished by the production of high-quality liquid hot metal on the basis of directly charged iron ore fines, and coal as the reductant and energy source.

A key feature of the FINEX® Process is that iron production is carried out in two separate process steps. In a series of fluidized-bed reactors, fine iron ore is reduced to direct reduced iron, compacted (HCI) and then transported to a melter-gasifier. Coal and coal briquettes charged to the melter-gasifier are gasified, providing the necessary energy for melting in addition to the reduction gas.

THE ORE ROUTE

Viewing the process from the ore route, a pneumatic conveying system transports the iron ore fines to the fluidized-bed reactor tower. The fine iron ore is then charged to a 3-stage fluidized-bed reactor series.

A reduction gas generated in the melter-gasifier flows through each of the fluidized-bed reactors in counter flow to the ore direction. The fine iron ore is fluidized by the gas stream and the ore is increasingly reduced in each reactor step. Following the exit of the reduced iron from the final fluidized-bed reactor, it is then compacted to so-called hot-compacted iron or HCI.

The HCI is subsequently transported via a hot-transport system to the top of the melter-gasifier where it is directly charged together with coal into the melter-gasifier. Final reduction and melting of the HCI then takes place.

THE COAL ROUTE

Viewing the process from the coal route, non-coking coals and coal briquettes are directly charged into the melter-gasifier through a lock-hopper system.

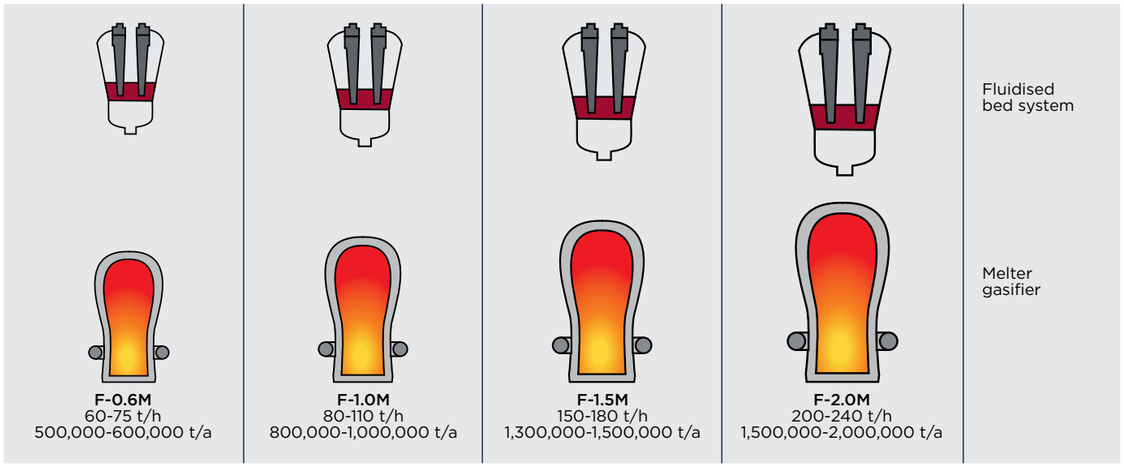
After the coal drops onto the char bed, degassing takes place. The released hydrocarbons, which are environmentally harmful, are immediately dissociated to carbon monoxide and hydrogen. This is due to the high prevailing temperatures exceeding 1,000 °C in the dome of the melter-gasifier. Oxygen injected into the lower part of the melter-gasifier gasifies the coal, generating heat for melting work as well as a highly valuable reduction gas comprised mainly of CO and hydrogen. This gas, which exits from the dome of the melter-gasifier, is first cleaned in a hot-gas cyclone before entering the fluidized-bed reactors. Following melting of the DRI, the tapping procedure is carried out exactly in the same manner as in standard blast furnace practice. The quality of FINEX® hot metal is identical to excellent blast furnace hot metal.

THE FINEX® EXPORT GAS

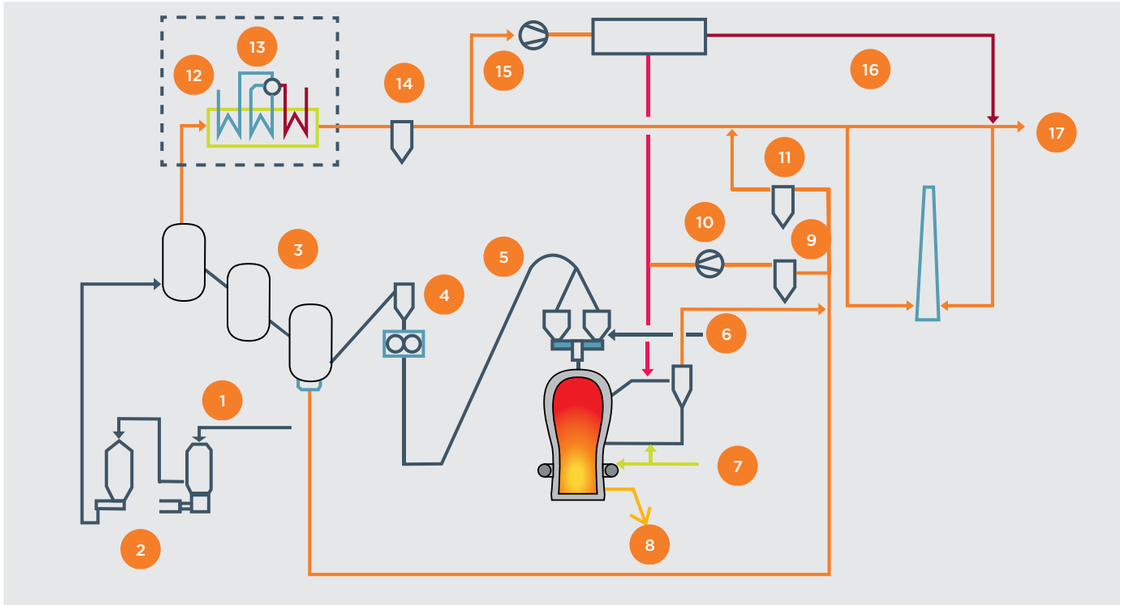
As another valuable by-product of the FINEX® Process, the clean export gas exiting from the top of the fluidized-bed reactors can be used for a wide variety of applications. These include production of DRI, power generation and the generation of synthesis gas for the chemical industry.

ADVANTAGES OF THE FINEX® TECHNOLOGY

- Direct utilization of low grade fine iron ores as oxide feed
- Direct utilization of non-coking coals as reducing agent
- Favorable economics - significantly decreased CAPEX and OPEX
- Environmental benefits
- Flexibility in raw materials selection and in the operation e.g. utilization of lower grade iron ores possible (e.g. iron ores with higher Al_2O_3 content)
- Production of hot metal which is identical to blast furnace hot metal quality
- Valuable export gas - can be utilized for different purposes (e.g. power generation, DRI production, chemical products)
- Commercial proven alternative iron making process to the blast furnace
- Brownfield application at integrated steel works gives synergies with the blast furnace



Available FINEX® module sizes

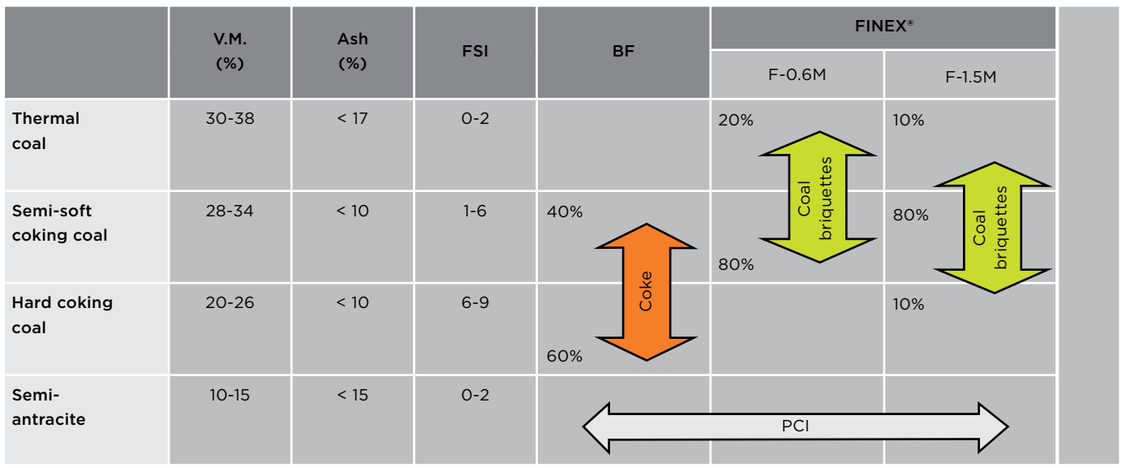


The typical FINEX® Process flow sheet

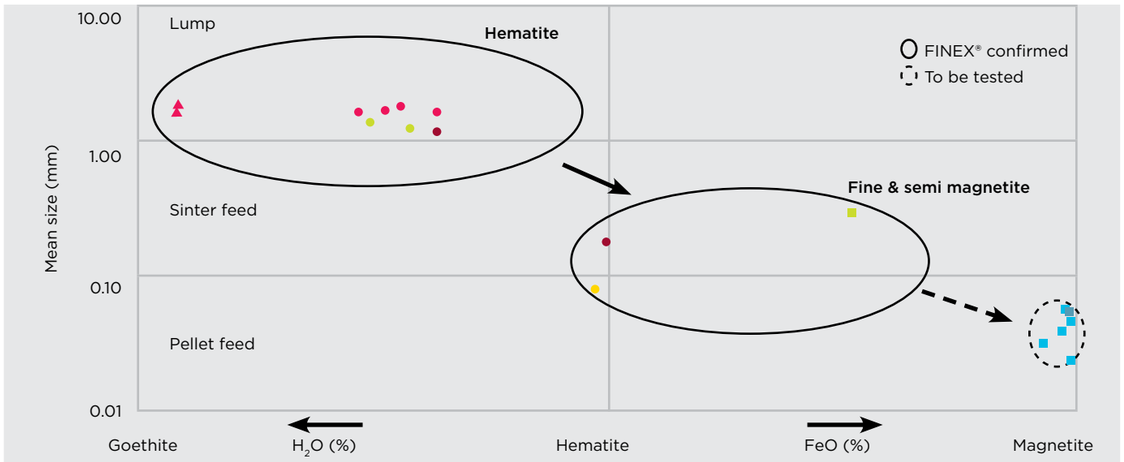
1 Ore, additive drier
2 Pneumatic ore transport
3 Fluidized bed
4 HCI (Hot compacted iron) plant
5 HCI (Hot compacted iron) Hot conveyor
6 Coal briquettes
7 Oxygen, PCI (Pulverised coal injection)
8 Hot metal, slag
9 CG (Cooling gas) scrubber
10 CGC (Cooling gas compressor)
11 EG (Excess gas) scrubber
12 Steam
13 Waste HRSG (Heat recovery steam generation)
14 TG (Top gas) scrubber
15 RGC (Recycle gas compressor)
16 Tail gas
17 Export gas to power plant and raw material drying

FLEXIBILITY IN RAW MATERIALS PRODUCING HIGH QUALITY PRODUCTS

MAKING OF THE DIFFERENCE



Coals utilized by FINEX®



Flexibility of ores suitable for FINEX®

TYPICAL CONSUMABLES FOR THE FINEX® PROCESS*)

*** Fuel rate (dry)	approx. 720 - 800 kg/t_{HM}
Ore	approx. 1600 kg/t_{HM}
Additives	approx. 285 kg/ t_{HM}
Oxygen	approx. 460 m^3 (STP**)/t_{HM}
Nitrogen	approx. 270 m^3 (STP**)/t_{HM}
Industrial water	approx. 1.5 m^3/t_{HM}
Electrical energy	approx. 190 kWh/t_{HM}
Refractories	approx. 1.5 kg/ t_{HM}

* depending on raw material qualities
** (STP) means standard temperature (0 °C) and standard pressure (1.013 bar abs.)
*** FR includes small size coke (0-30 mm, approx. 50-100 kg/t_{HM}

COAL

The major criteria for an initial evaluation of coals or coal blends suitable for the FINEX® Process are:

- fix carbon content at a minimum of 55%
- ash content up to 25%
- volatile content lower than 35%
- sulphur content lower than 1%

In addition to these general criteria the coals have to meet certain requirements related to thermal stability in order to allow for the formation of a stable char bed in the melter gasifier. The thermal stability of potential coals for the FINEX® Process is checked using special testing procedures in laboratories.

FINEX®, unlike the blast furnace, can operate without coke due to the lower burden load in the melter gasifier char bed and the use of oxygen. Cokeless operation was performed for about one year in 2012 and has been intermittently conducted for one or two months.

Due to changing coal briquette quality and reduction degree fluctuations some coke breeze (<30mm) typically was used before and after a shutdown or in case of a decreasing hot metal temperature to maintain productivity and decrease fuel ratio. The current operation provides a constant level of coke breeze to minimize the above described effects. It has to be mentioned that the coke breeze quality used is not suitable for the blast furnace and has strength of approx. 60% of blast furnace coke only.

To achieve a zero coke breeze operation in the near future, many operation optimizations are under way, e.g. binder optimization or ongoing development of a coal briquette pre-heating technology.

OXIDE

In general, 100% of sinter feed fine ore is charged into fluidized bed reactors. 30-50% of pellet feed is also applicable. Brands and mix of iron ore are decided in consideration of chemical and physical properties such as total Fe content, composition structure, grain size, etc.

In the same manner as of blast furnace process, the Fe content of iron ore determines the productivity. The mixing ratio should be decided by considering ore quality and the price together. Since higher alumina slag tapping is more tolerable in FINEX® than in blast furnace, higher alumina content of iron ore is also allowable. Generally, there is no limitation in feeding material structure of hematite and goethite for fluidized bed reactors.

PRODUCTS OF THE FINEX® PROCESS

Hot metal

The chemical composition of the FINEX® hot metal is identical to that of excellent blast furnace hot metal.

TYPICAL CHEMICAL ANALYSIS AND TEMPERATURE OF FINEX® HOT METAL

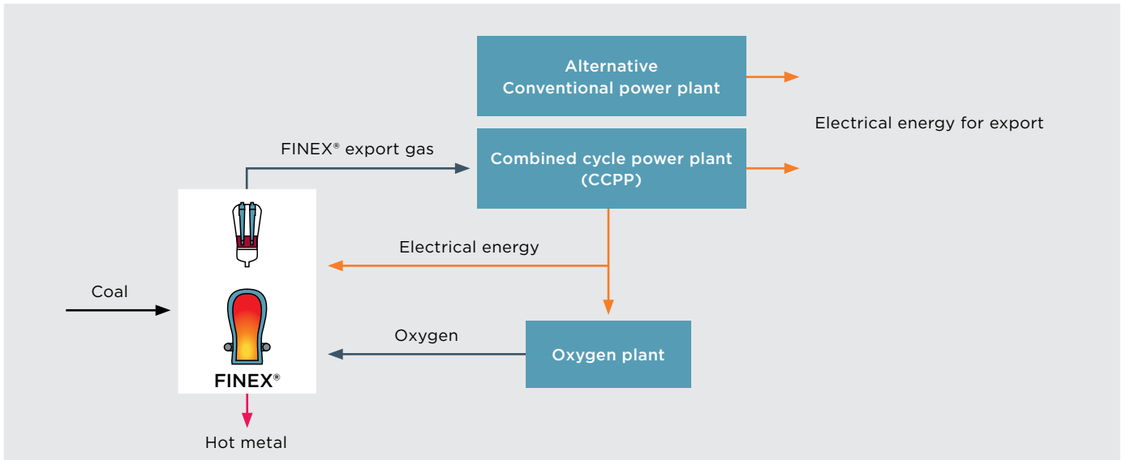
Tapping temperature	1500 °C
C	4.50%
Si	0.70%
P	0.07%
S	0.04%
Mn	0.07%

Export gas

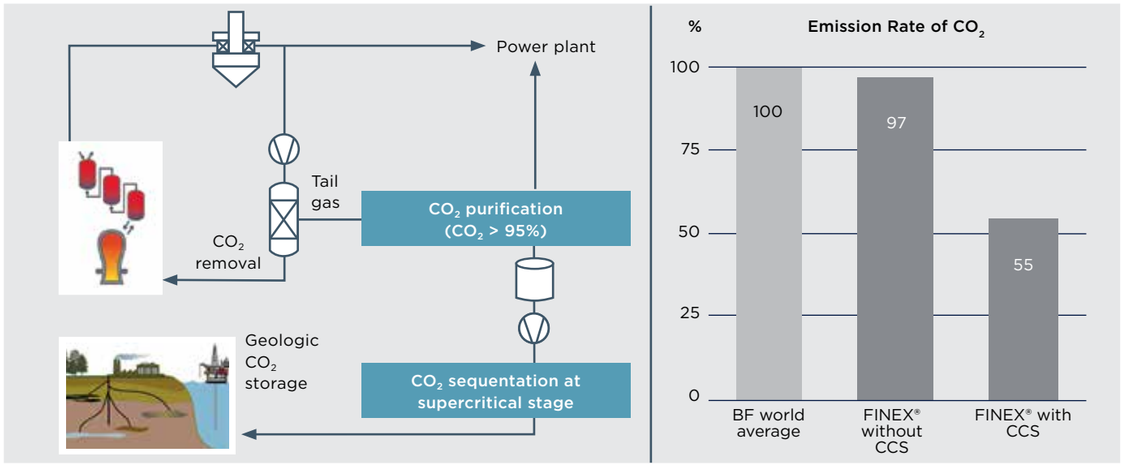
TYPICAL CHEMICAL ANALYSIS OF FINEX® EXPORT GAS

CO	34%
CO_2	43%
H_2	13%
H_2O	3%
CH_4	1%
N_2/Ar	6%
H_2S	<100 ppmv
Dust	5 mg/m^3(STP)
Pressure	10 kPa g
Temperature	40 °C
Calorific value	5500 - 6250 kJ/m^3(STP)
Export gas credit	approx. 8 GJ/t_{HM}

FROM POWER GENERATION TO ENHANCED PRODUCTIVITY
ADDITIONAL BENEFITS



Generation of electric power



Great potential for further CO_2 mitigation due to the use of pure oxygen

UTILIZATION OF THE FINEX® EXPORT GAS

The export gas is a mixture of the not recycled off-gas, excess gas and the tail gas of the Pressure Swing Adoption (PSA) plant. Even the calorific value of the direct reduction export gas is higher than blast furnace top gas and, similar to the COREX® export gas, FINEX® export gas can substitute natural gas, oil, coke and coal for numerous applications, including:

- electrical power generation
- DRI production
- heating purposes
- steam generation
- raw material drying
- pelletizing plant
- production of synthesis gas
- biofermentation
- chemical products

ADJUSTABLE EXPORT GAS GENERATION

Depending on the composition of coal and the decision whether gas recycling is applied or not, the amount and the composition of the export gas can vary within definite limits.

PRODUCTION OF ELECTRICAL ENERGY

Regardless of the recycling decision and plant setup, with its excellent calorific value the FINEX® export gas is best suited for power generation.

When used in a combined-cycle power station, the export gas is converted to electrical energy with efficiencies up to 46%.

Depending on particular site conditions, a tailor-made production route including power generation fulfils all requirements for optimized energy management. Beyond that, operators benefit from value created by surplus electricity, which can be used to supply public demand.

PRODUCTION OF DRI

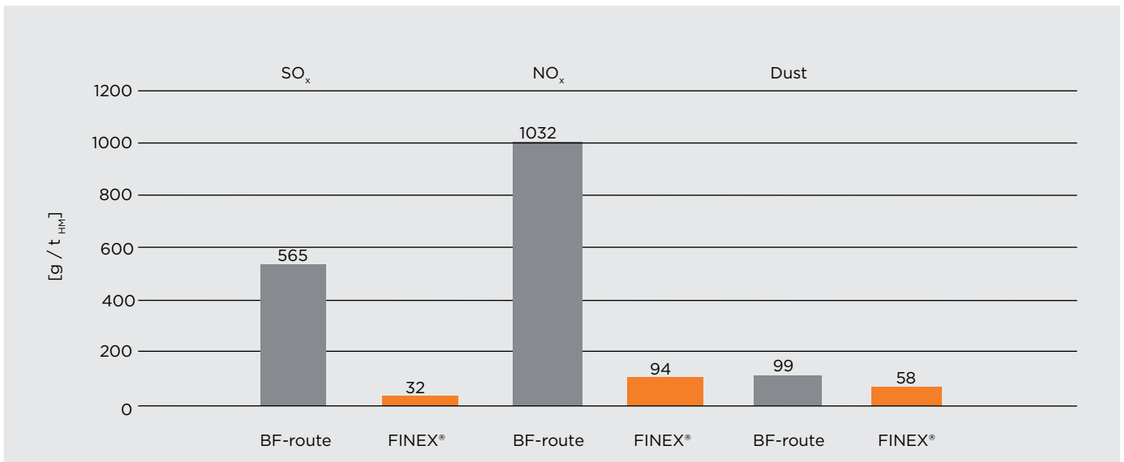
Another way to benefit from the surplus reduction potential is to reheat and utilize the export gas in a downstream direct reduction plant.

LOWEST SPECIFIC CONSUMPTION RATES AND GREAT POTENTIAL FOR CO_2 MITIGATION

The FINEX® Process also offers the possibility to generate high purity CO_2 to be further available for sequestration, oil recovery enhancement or other economical use. Based on the fact that high purity oxygen in the melter gasifier is used to gasify coal, the export gas composition contains only low amounts of nitrogen.

This fact allows to scrub out the CO_2 in high concentration from the recycling gas and to generate after further purification high purity CO_2 (CO_2 > 95%).

PROFITABLE AND ENVIRONMENTALLY FRIENDLY
PREPARED FOR PRESENT AND FUTURE IRONMAKING CHALLENGES



Emission comparison blast furnace route vs. FINEX®

The FINEX® F-1.5M plant and FINEX® Demonstration Plant at POSCO Pohang

ENVIRONMENTALLY COMPATIBLE HOT METAL PRODUCTION

The FINEX® Process and the blast furnace route are coal based processes reducing iron ore to iron, which is subsequently melted into hot metal. In both processes, the same product is generated out of almost the same raw material. A question that arises – and not only from an economic point of view – is "how do these production routes deal with unwanted impurities?"

A certain amount of environmentally harmful substances are inevitable based on the raw material mix. Hence, the objective of a sustainable iron making process is to discharge these substances in an environmentally compatible condition, or destroy them in the process itself. Since the FINEX® Process captures most of the pollutants in an inert state in the slag and the released hydrocarbons are destroyed in the dome of the melter gasifier, no additional investment or operational costs are incurred for a complex gas or disproportional waste water conditioning plant.

FUTURE-PROOF EMISSION FIGURES

Minimizing the emission values for the blast furnace route requires the highest investment for environmental protection, disregarding all reasonable economic aspects. This can already be seen in the case of blast furnace dust emissions, where efficient, but costly filter systems are installed in the sinter and coking plant.

The FINEX® Process values are already far better than expected future standards. Moreover, the full development potential of the FINEX® Process has not yet been realized with respect to a further reduction of emissions.

GASEOUS EMISSIONS

Thanks to the in-situ coking of the coal in the melter gasifier, a large portion of sulfur is captured in the slag, thus dramatically decreasing emissions of gaseous SO_2 or H_2S. Furthermore, pure oxygen is used instead of the hot air blast, significantly reducing nitrogen emissions in the form of NO_x and providing the advantages already mentioned regarding dust emissions.

EVEN GREATER POTENTIAL

Because the FINEX® Process is still being optimized, additional economic and technological benefits are anticipated. Major developments are continuously being carried out to increase efficiency. The latest achievements include breakthroughs in the field of heat recovery, dry dedusting, and outstanding performance improvements.

Based on the well-proven plant concept, new process features, the highly competitive production costs, and environmental features, Primetals Technologies and POSCO are confident that the FINEX® Process will account for an increasing share of future investments in iron making facilities.

ECONOMIC CONSIDERATIONS

The unique characteristics of the FINEX® Process and its ability to use low-cost raw materials mean that both capital investment and production costs are considerably lower than the blast furnace route. Typically FINEX® F-1.5M plant can save operators up to 10% in hot metal production costs in comparison to the traditional blast furnace route.

COST COMPETITIVENESS

- Low CAPEX
  - Elimination of expensive coking & sintering plants
  - Compact land use
  - Lower construction volume
  - Lower investment for integration facilities and utilities e.g. power and utlities distribution, road network etc.
- Lower OPEX
  - No need for high ranking coal, sinter & pellets
  - No need for blending raw materials

FINEX® REFERENCES
SEVERAL SUCCESS STORIES

POSCO POHANG WORKS (KOREA) – FINEX® F-0.6M DEMONSTRATION PLANT

The plant commenced operation in 1995 as the first COREX® C-2000 plant. In parallel the FINEX® research and development started. Following initial laboratory and pilot-plant tests for the FINEX® Process, the existing Corex C-2000 plant was converted to the FINEX® F-0.6M Demonstration Plant which commenced operations in May 2003. And after just a few months, it became clear that the production target would not only be met but also exceeded, with the same plant now producing 800,000 tons of high quality hot metal per year. The plant was shut down in July 2014 and is to be relocated to India.

POSCO POHANG WORKS (KOREA) – FINEX® F-1.5M PLANT

On the basis of the successful results achieved at the FINEX® F-0.6M Demonstration Plant and following optimization of equipment and process parameters, the decision was quickly taken to build the bigger sized FINEX® F-1.5M plant having a nominal production capacity of 1.5 million tons of hot metal per year. This plant commenced operation in April 2007.

POSCO POHANG WORKS (KOREA) – FINEX® F-2.0M PLANT

The FINEX® F-2.0M plant for the annual capacity of 2.0 million tons of hot metal succesfully commenced operation in January 2014.

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