

The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook

Raw materials through Steelmaking, including Recycling Technologies, Common Systems, and General Energy Saving Measures

Asia Pacific Partnership for Clean Development and Climate

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The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook

Asia Pacific Partnership for Clean Development and Climate

Prepared for the Asia-Pacific Partnership on Clean Development and Climate,
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Introduction

The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook seeks to catalog the best available technologies and practices to save energy and reduce environmental impacts in the steel industry. Its purpose is to share information about commercialized or emerging technologies and practices that are currently available to increase energy efficiency and environmental performance between all the member countries in the Asia-Pacific Partnership on Clean Development and Climate.

Steel is used in many aspects of our lives, in such diverse applications as buildings, bridges, automobiles and trucks, food containers, and medical devices, to name a few. Steel provides substantial direct employment in the Asia-Pacific Partnership on Clean Development and Climate (APP) countries, and provides a significant direct contribution to the APP economies. Countless additional jobs and economic benefits are provided in steel industry supply and support activities, including mining, capital equipment supply, utilities and many community industries.

The aggregate carbon dioxide (CO_2) emissions from the global steel industry have reached roughly two billion tons annually, accounting for approximately 5% of global anthropogenic CO_2 emissions. Countries in the APP account for more than 57% of global steel production. The APP Steel Task Force, therefore, has significant potential to reduce CO_2 emissions and conserve energy by sharing information on clean technologies, and by cooperating to implement such technologies. To enable these efforts, the Partnership will emphasize public–private cooperation to reduce or remove barriers to technology implementation.

Figure 1: Some Steel Applications



The production process for manufacturing steel is energy-intensive and requires a large amount of natural resources. Energy constitutes a significant portion of the cost of steel production, up to 40% in some countries. Thus, increasing energy efficiency is the most cost-effective way to improve the environmental performance of this industry.

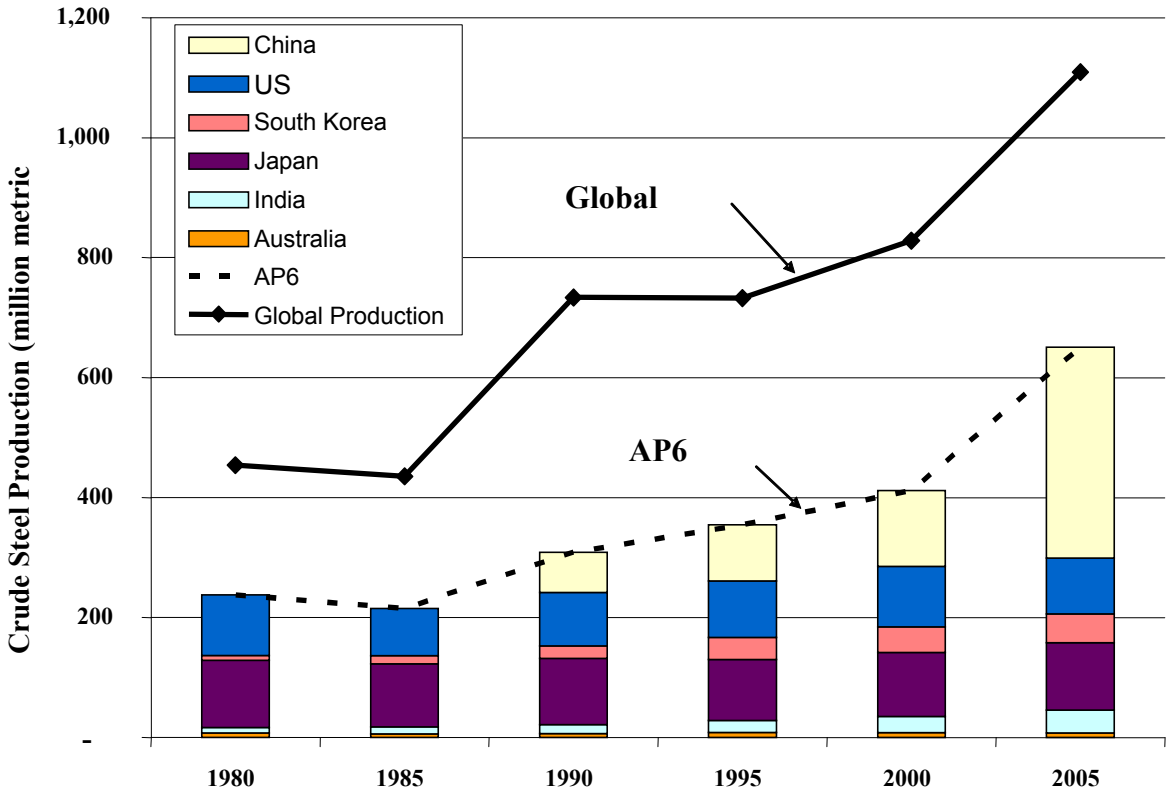
To address these issues, there has been significant investment in new products, plants, technologies and operating practices. The result has been a dramatic improvement in the performance of steel products, and a related reduction in the consumption of energy and raw materials in their

manufacture. Recent developments have enabled the steel industry's customers to improve their products through better corrosion resistance, reduced weight and improved energy performance. This improvement is seen through a wide range of products, including passenger cars, packaging and construction materials.

The steel industry is critical to the worldwide economy, providing the backbone for construction, transportation and manufacturing. In addition, steel has become the material of choice for a variety of consumer products, and markets for steel are expanding. Steel, already widely regarded as a high performance contemporary engineering material, is continuously being improved to meet new market demands. Globally, and in the APP countries, steel production is experiencing historic levels and continuing to grow. Figure 2 shows the expansion of crude steel production for APP countries and worldwide from 1980 to 2005.

Traditionally valued for its strength, steel has also become one of the most recycled materials. At the end of their useful life, products containing steel can be converted back into "new" steel, ready for other applications. Furthermore, the steel production process can utilize wastes and by-products as alternative reductants and raw materials, which reduces overall CO_2 emissions per ton of steel produced. In 2005, almost 43% of global crude steel production came from recycled steel. However, recycling rates vary significantly among products and countries.

Figure 2: Steel production is growing in new and established markets



Source: Worldsteel.org, Data for China not available prior to 1990

Steel Production Basics

Steel is an alloy consisting of iron, with a carbon content of between 0.02% and 2% by weight, and small amounts of alloying elements, such as manganese, molybdenum, chromium or nickel.

Steel has a wide range of properties that are largely determined by chemical composition (carbon and other alloys), controlled heating and cooling applied to it, and mechanical "working" of the steel in the finishing process.

The production of steel requires a number of steps, which can include:

1. Agglomeration processes
    - 1.1 Sintering
    - 1.2 Pelletizing
    - 1.3 Briquetting
2. Cokemaking
3. Ironmaking by:
    - 3.1 Blast Furnace
    - 3.2 Direct Reduction
    - 3.3 Direct Ironmaking
4. Steelmaking by:
    - 4.1 Basic Oxygen Furnace (BOF) Steelmaking
    - 4.2 Electric Arc Furnace (EAF) Steelmaking
5. Ladle refining and casting
    - 5.1. Ladle Refining for BOF and EAF
    - 5.2. Casting
6. Rolling and Finishing
    - 6.1 Rolling and Forming
    - 6.2 Finishing

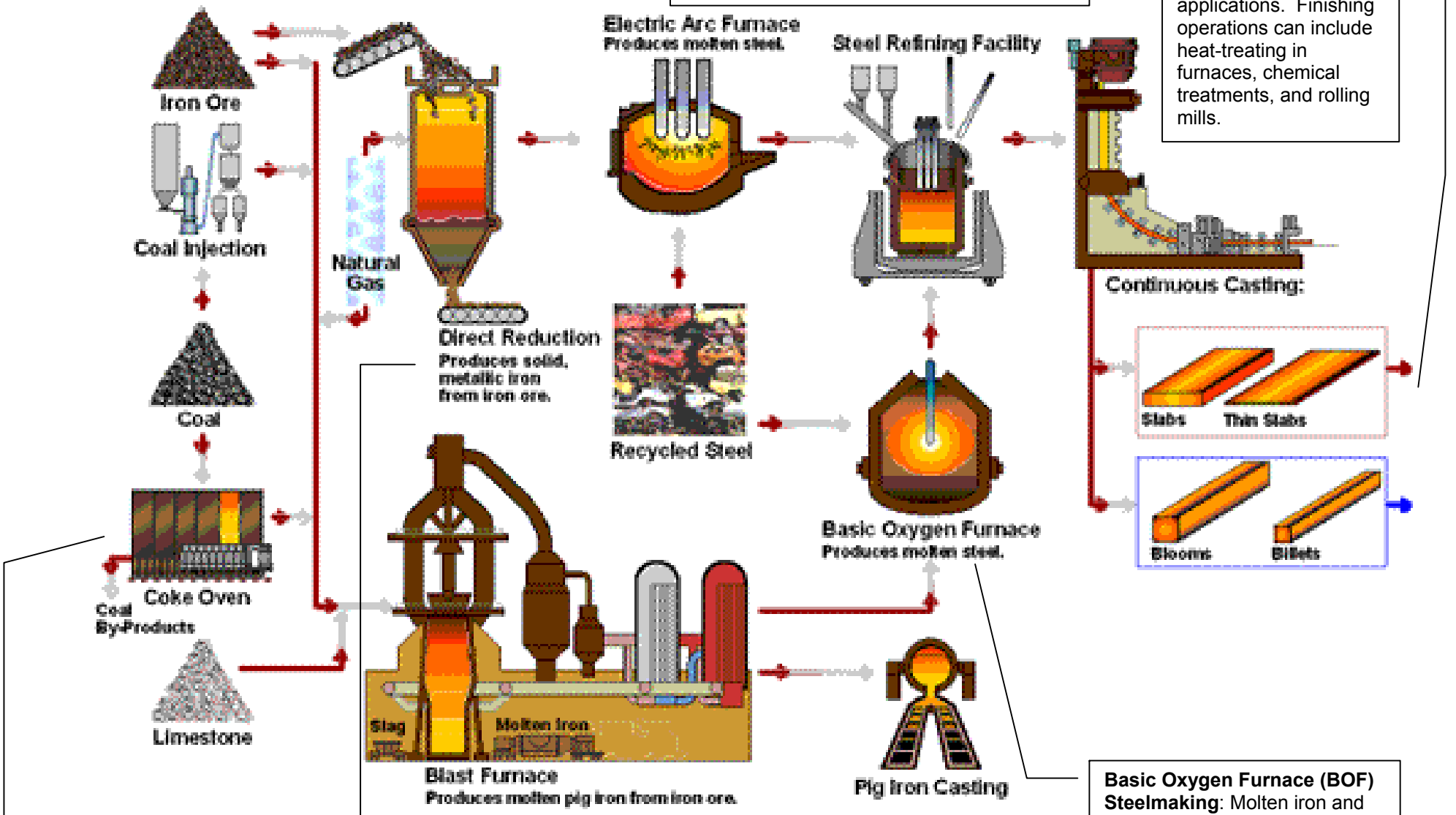
Figure 3: Charging of a BOF



Source: http://www.stahl-online.de

Steel production is a batch process. The two most common routes are a blast furnace in combination with a BOF, commonly referred to as "integrated" steelmaking, and a principally scrap based EAF, commonly referred to as the "minimill". Process steps associated with these two methods of steel production are illustrated in Figure 4.

Figure 4: Basic Flows of Steel Production



Electric Arc Furnace (EAF) Steelmaking: Molten iron and scrap are converted to steel by high-powered electric arcs. Molten steel from the BOF or EAF is refined by the addition of alloys and is cast into solid forms for delivery to the finishing process.

Finishing: Steel is shaped into forms for varying industrial applications. Finishing operations can include heat-treating in furnaces, chemical treatments, and rolling mills.

Cokemaking: Coal is converted to coke for use in a blast furnace.

Ironmaking: Iron ore is reduced to iron in a blast furnace or direct reduction furnace.

Basic Oxygen Furnace (BOF) Steelmaking: Molten iron and scrap are converted to steel by the injection of oxygen.

1. Agglomeration

Materials preparation for ironmaking using a blast furnace involves two processes: iron ore preparation and cokemaking.

As a shaft furnace, a blast furnace requires the raw materials to form a permeable bed that will permit gases to pass through it. While lump iron ore can be used directly, iron ore ***agglomerating processes*** can improve the iron content and/or physical properties of the ore. Iron feed materials from such processes usually contain between 50% to 70% iron by weight.

The agglomeration processes are sintering, pelletizing and briquetting.

Figure 5: Sinter Plant



Source: Japan Iron and Steel Federation

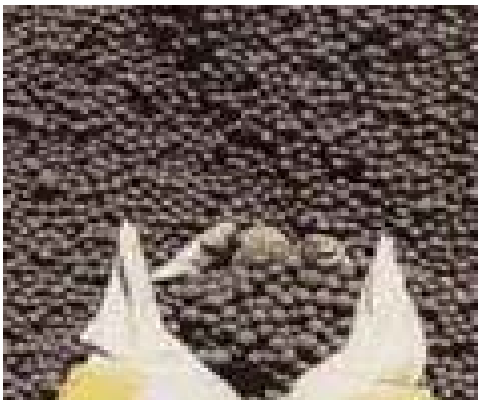
1.1 Sintering

In sintering, iron ore fines, other iron-bearing wastes and coke dust are blended and combusted. The heat fuses the fines into coarse lumps that can be charged to a blast furnace. While sintering enables the use of iron ore fines, major issues are the large capital investment and the need for air pollution control strategies.

1.2 Pelletizing

In pelletizing, iron ore is crushed and ground to enable some of the impurities to be removed. The beneficiated (iron-rich) ore is mixed with a binding agent and then heated to create durable marble-sized pellets. These pellets can be used in both blast furnaces and direct reduction.

Figure 6: Pellets



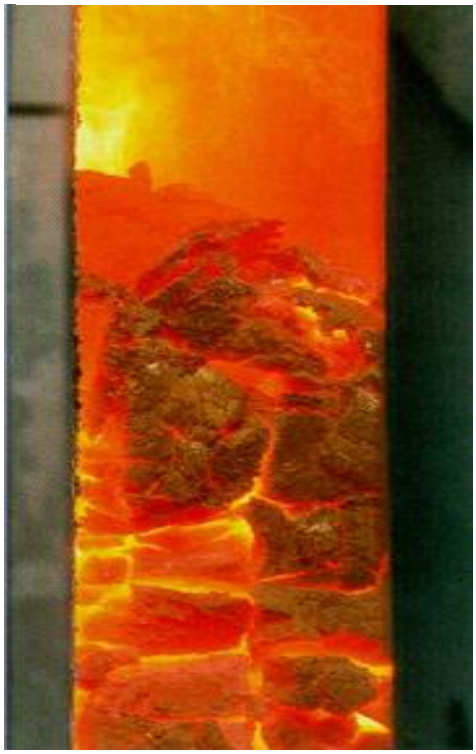
1.3 Briquetting

In briquetting, crushed ore or fines are heated and compressed to produce briquettes.

2. Cokemaking

Coke is produced from metallurgical grade coals and is an essential part of integrated steelmaking, because it provides the carbon to remove the oxygen from iron ore and the heat to produce molten iron in the blast furnace. Due to its strength and porous nature, coke is an important contributor to the formation of the permeable bed required for the optimization of blast furnace performance. Cokemaking represents more than 50% of an integrated steelmaking's total energy use.

Figure 7: Incandescent coke in the oven



In the cokemaking process coal is heated in an oxygen-deficient atmosphere to drive off the hydrocarbon content of the coal, leaving the remaining carbon as the coke product. Coke production is achieved via a battery of large ovens consisting of vertical chambers separated by heating flues.

In by-product cokemaking, the off-gases are collected and treated to be used as an energy source elsewhere in the steel production process, increasing overall energy efficiency. In non-recovery cokemaking, the hydrocarbon off-gases are not recovered.

Major issues for cokemaking include availability of suitable coking coals, large capital investment and air pollution control strategies.

Figure 8: Hot coke being pushed from a Coke Oven Battery. The railroad car is full of incandescent coke.



3. Ironmaking

Ironmaking is the process of reducing iron ore (solid oxidized iron) into iron through the removal of the oxygen. This conversion is the most energy-intensive stage of the steel process and has the largest CO_2 emissions.

The most common method of producing iron – accounting for more than 90% of world iron production – involves the blast furnace, which is a shaft furnace containing a bed of iron ore as lump, sinter, pellets or briquettes, along with coke and a fluxing agent (usually limestone) that produces molten iron. The molten iron is commonly known as "pig iron". The heat for the process comes from the burning of the coke using hot air that is passed through the bed. This burning of the carbon in the coke not only produces the heat to melt the iron, but also provides the reducing gas (mainly carbon monoxide (CO)) that strips the oxygen from the ore.

The other significant method of producing iron involves the direct reduction of iron ore using a reducing gas to produce direct reduced iron (i.e., with the bulk of its oxygen removed in a solid state). This iron is commonly known as "direct reduced iron" (DRI), and may be subsequently melted or made into briquettes.

There are a number of other methods of producing iron, which collectively are called "direct ironmaking" and are based on the desirability of using non-coking coals and avoiding the need to agglomerate the ore.

Figure 9: Iron from a blast furnace being poured into a torpedo car

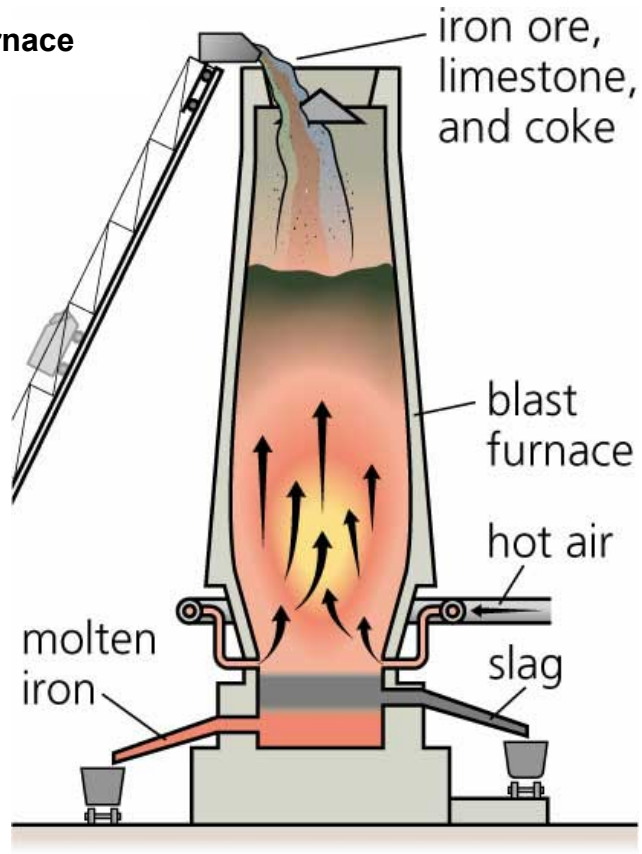


Courtesy of U.S. Steel

3.1 Blast Furnace

The blast furnace is a tall cylindrical counter current shaft furnace lined with refractory brick. The iron ore feed material, along with coke and limestone, are charged into the top of the furnace. These materials pass down through the furnace in the opposite direction to the reduction gases. As the material moves downward, the oxygen content of the iron ore feed material is progressively removed by the reducing gases that are passing up through the bed. Heat and reducing gases are generated by the combustion of the coke with preheated air. This preheated air at around 1000-1200°C is introduced into the lower region of the vessel through tuyeres. Molten iron and slag (which is a collection of the fluxing agent and the residual components from the iron ore and coke), collect in the bottom of the vessel and are tapped periodically. The iron produced from the blast furnace contains about 94% iron with greater than 4% carbon. The iron, as tapped, is too brittle for most engineering applications and therefore is further refined into steel.

Figure 10: Blast Furnace

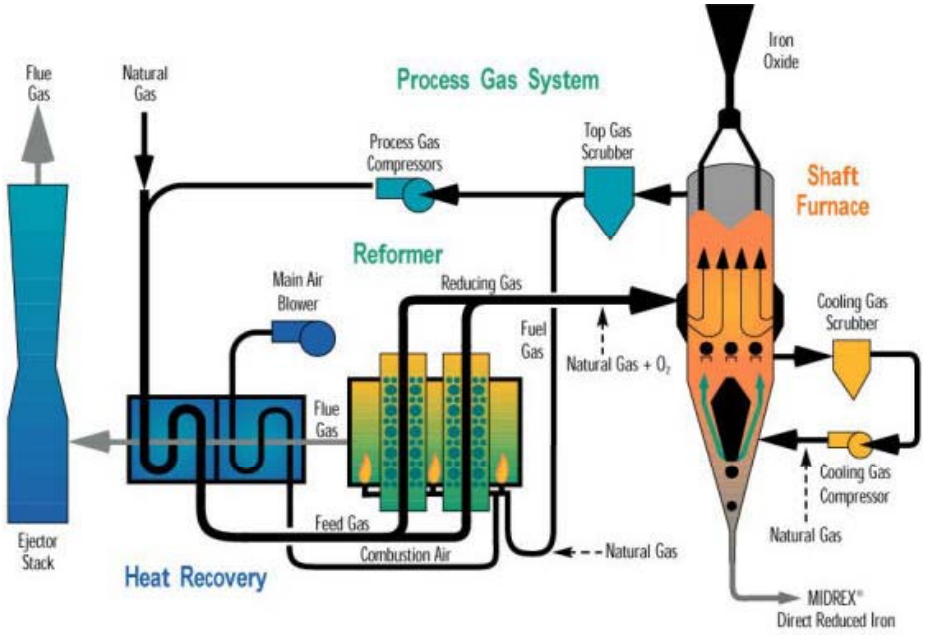


3.2 Direct Reduction

Direct reduction processes require a reducing gas to remove the oxygen from the iron containing material in a solid state. The reducing gas is in the form of CO and/or H_2. The majority of DRI in the world is produced in shaft furnaces, with natural gas as the feedstock for the reducing agent.

In shaft-based versions, which operate on a counter current basis like blast furnaces, the gas must be able to pass freely through the bed. Accordingly, pellets are the preferred iron ore feed material, with the iron ore feed material being charged into the top of the shaft. As with blast furnaces, this material passes down through the furnace in the opposite direction to the reduction gases, and as the material moves downward, the oxygen content of the iron ore feed material is progressively removed by the reducing gases that are passing up through the bed. Pre-heated reducing gases are introduced into the middle of the vessel. The reducing gases are created external to the shaft by preheating and reforming the reduction products coming from the top of the vessel using natural gas and/or coal. The pre-reduced solid iron is cooled and removed from the bottom of the shaft. An example of one shaft based process is shown below.

Figure 11: MIDREX DRI Process



Direct reduction processes that are based on natural gas have lower emissions (including CO2) than integrated plants that use coke ovens and blast furnaces. DRI is favored by electric arc furnace (EAF) steelmakers, who blend it as a feedstock with lower quality scrap to improve the steel quality. Direct reduction processes tend to be located near readily available natural gas supplies, but often have higher fuel costs compared to coal/coke based processes. The amount of DRI that can be charged into an EAF is limited by remaining residue oxygen, which increases steelmaking energy

requirements. For good quality DRI the iron ore used must have low levels of impurities (gangue). Processed ores below 65% iron are usually considered unsuitable.

3.3 Direct Ironmaking

Concerns over limited long term supply of coking coals and the environmental impact of both coking and sinter plants have provided the drivers for the development of alternative ironmaking processes that use non-coking coals to reduce iron ores directly. These emerging direct ironmaking processes can be categorized by those producing molten iron (similar in quality to the blast furnace), and those producing a solid direct reduced iron.

3.3.1 Smelt Reduction Processes

The smelt reduction processes can be further differentiated by whether there is significant direct reduction occurring prior to producing the molten metal.

For those with direct reduction steps, like the Corex and Finex processes, the smelting reduction is achieved using counter current direct reduction in a shaft furnace in combination with a melter-gasifier. Here the gas for the direct reduction shaft furnace is created by feeding coal into a vessel that also receives hot DRI for melting. The coal is devolatilized by the heat in the furnace to produce a reduction gas of CO and H_2, and a bed of char. Oxygen is injected lower down into the vessel where it reacts with the char to produce heat and further CO. The heat from the combustion of the char melts the DRI and the molten metal collects in the hearth. The metal and slag are tapped periodically in the same manner as with a blast furnace operation.

In the direct smelting processes (i.e., those without a direct reduction step), like the HIsmelt, Ausiron and Romelt processes, all the feed materials are fed to a molten bath of metal and slag, where the iron ore feed materials are reduced to molten iron in a matter of seconds. The gases generated by the devolatilisation of the coal and reduction of the iron ore are combusted by using oxygen or oxygen enriched hot air, with the heat generated returned to the bath by the metal and slag layer.

3.3.2 Direct Reduction Processes

The direct reduction processes produce a solid product or direct reduced iron product from coal and iron ore fines or waste oxides. Technologies such as the Fastmet and ITmk3 processes utilize a rotary hearth furnace.

4. Steelmaking

Steelmaking is the production of molten iron with a carbon content of between 0.02% and 2% by weight. This is accomplished using either a Basic Oxygen Furnace or an Electric Arc Furnace. Both processes produce batches of steel know as “heats”.

4.1 Basic Oxygen Furnace (BOF) Steelmaking

The basic oxygen furnace (BOF) is charged with molten iron and scrap. The term “basic” refers to the magnesia (MgO) refractory lining of the furnace.

Oxygen is injected through a water-cooled lance, resulting in a tremendous release of heat through the oxidation of carbon in the molten iron, with the CO providing vigorous mixing of the charge as it leaves the vessel. Aside from the oxygen, there is no fuel source needed to provide additional thermal energy. However, to maintain the auto-thermal process, the amount of scrap that can be charged is limited to about 30%. Steel is created when the carbon content of the iron charge is reduced from about 4% to less than about 2% (usually <1%).

After the molten steel is produced in the BOF and tapped into ladles, it may undergo further refining in a secondary refining process or be sent directly to the continuous caster, where it is solidified into semi-finished shapes: blooms, billets or slabs.

Figure 12: Basic Oxygen Furnace

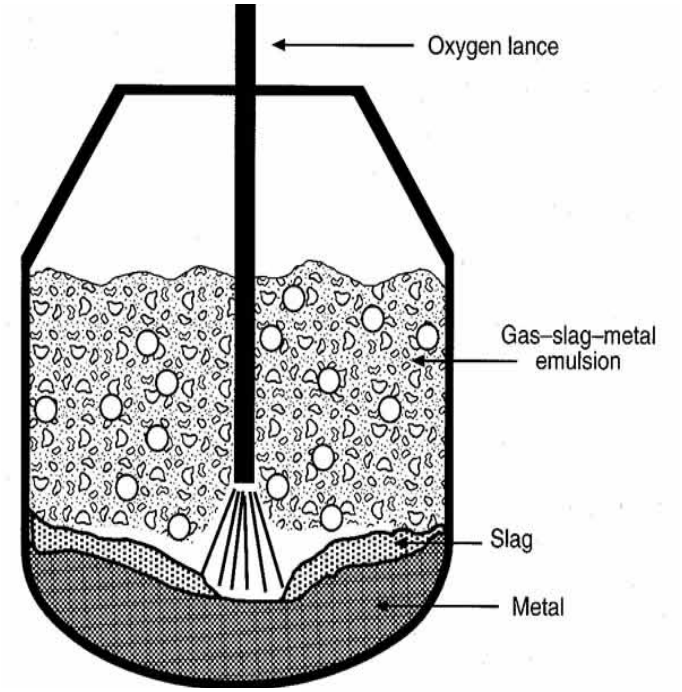


Table 1: Production of BOF Steel

	Production (million tonnes)
Australia	6.4
China	304.3
India	20.0
Japan	83.7
South Korea	26.7
USA	42.7
APP Total	483.9
Worldwide	738.8

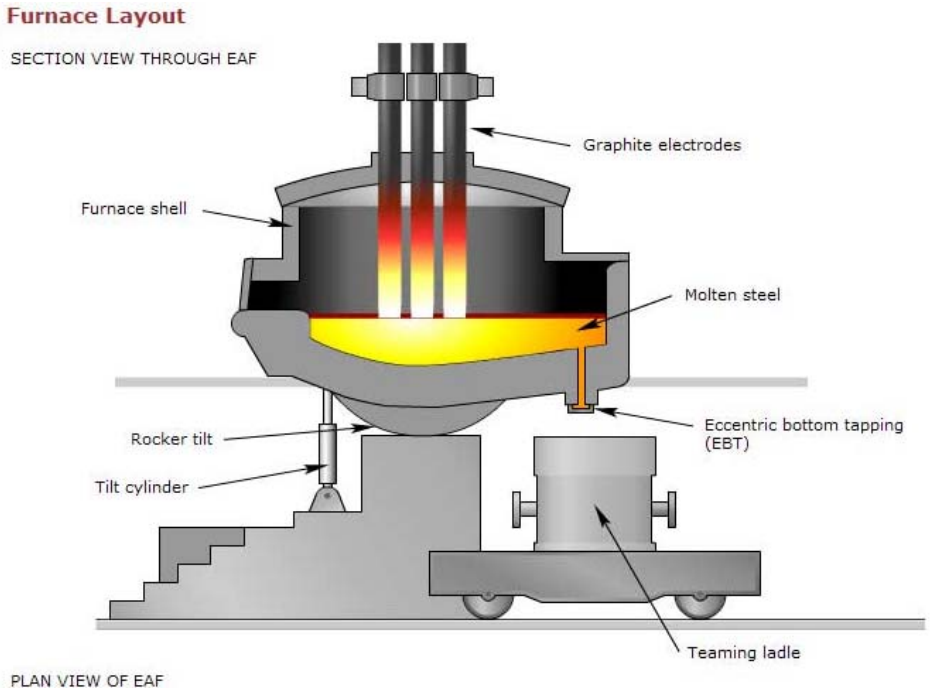
Source: Worldsteel.org

BOF steelmaking represents about 75% of steel production in the APP countries. Of all BOF steel produced globally, APP countries produce about 65%. Table 1 compares the production of BOF steel in 2005 in the APP countries and worldwide.

4.2 Electric Arc Furnace (EAF) Steelmaking

Electric arc furnace (EAF) steelmaking uses heat supplied from electricity that arc from graphite electrodes to the metal bath to melt the solid iron feed materials. Although electricity provides most of the energy for EAF steelmaking, supplemental heating from oxy-fuel and oxygen injection is used.

Figure 13: Electric Arc Furnace Diagram



The major advantage of EAF steelmaking is that it does not require molten iron supply. By eliminating the need for blast furnaces and associated plant processes like coke oven batteries, EAF technology has facilitated the proliferation of mini-mills, which can operate economically at a smaller scale than larger integrated steelmaking. EAF steelmaking can use a wide range of scrap types, as well as direct reduced iron (DRI) and molten iron (up to 30%). This recycling saves virgin raw materials and the energy required for converting them. Table 2 compares the production of EAF steel in 2005 in the APP countries and worldwide.

Table 2: Production of EAF Steel

	Production (million tonnes)
Australia	1.4
China	45.1
India	17.1
Japan	28.8
South Korea	21.1
USA	52.2
APP Total	165.6
Worldwide	358.1

Source: Worldsteel.org

The EAF operates as a batch melting process, producing heats of molten steel with tap-to-tap times for modern furnaces of less than 60 minutes.

EAF steelmaking represents about 25% of steel production in the APP countries. APP countries produce 46% of all EAF steel produced globally.

Current ongoing EAF steelmaking research includes reducing electricity requirement per ton of steel, modifying equipment and practices to minimize consumption of the graphite electrodes, and improving the quality and range of steel produced from low-quality scrap.

5. Ladle Refining and Casting

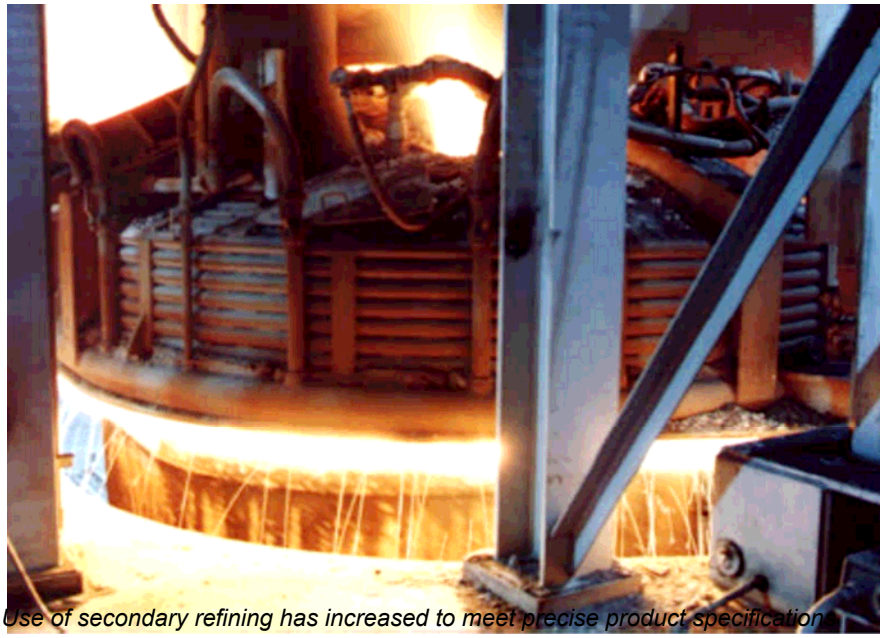
After the molten steel is produced in the BOF or EAF and tapped into ladles, it may undergo further refining or be sent directly to the continuous caster where it is solidified into semi-finished shapes: blooms, billets or slabs. The casting of near-net shapes saves energy during further downstream processing.

The undertaking of a refining step prior to continuous casting can improve the efficiency of both the downstream casting and the upstream steelmaking steps. Continuous casting is most efficient when multiple ladles of a consistent steel grade can be fed through the caster. To do this, steps such as “trimming” the steel composition before casting are required. If such steps are undertaken outside of the BOF or EAF it reduces the overall tap-to-tap times of the BOF or EAF and thus maximizes their efficiency.

5.1 Ladle Refining for BOF and EAF

After steel is created in a BOF or EAF, it may be refined before being cast into a solid form. This process is called “ladle refining”, “secondary refining” or “secondary metallurgy”, and is performed in a separate ladle/furnace after being poured from the BOF or EAF.

Figure 14: Ladle Metallurgy Furnace



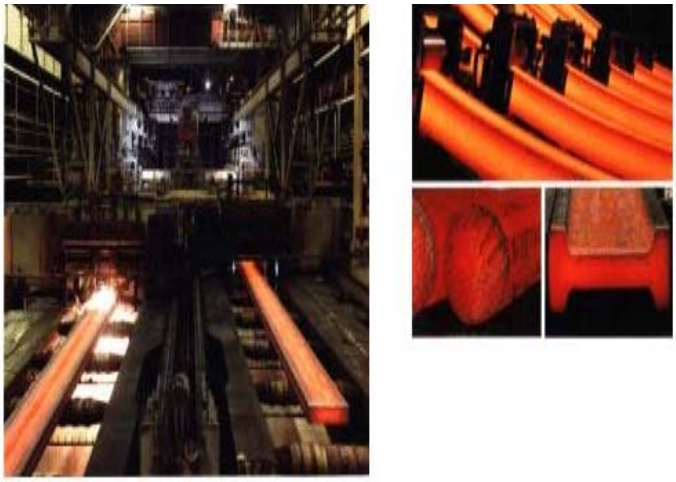
Use of secondary refining has increased to meet precise product specification

Steel refining helps steelmakers meet steel specifications demanded by their customers. Refining processes include: chemical sampling; adjustments for carbon, sulfur, phosphor and alloys; vacuum degassing to remove dissolved gases; heating/cooling to specific temperatures; and inert gas injection to “stir” the molten steel.

5.2 Casting

Casting is the production of solid steel forms from molten steel.

Figure 15: Continuous Casting: Molten steel is simultaneously cooled and formed into long strands of steel.

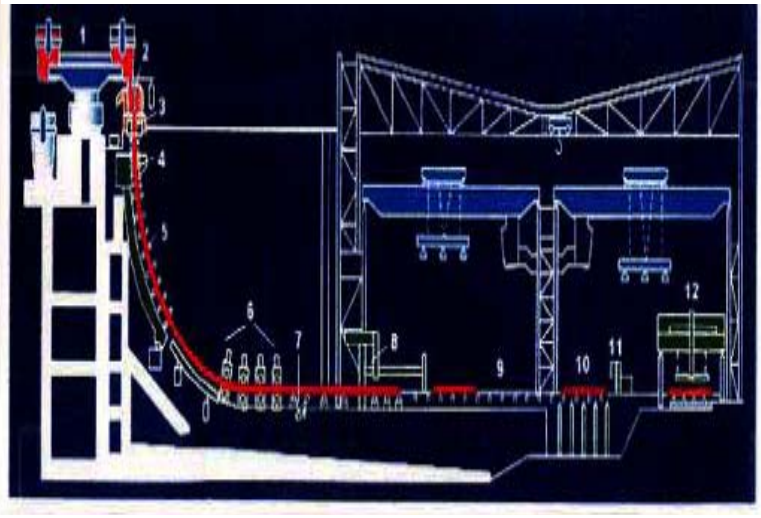


Casting begins when refined steel is poured from a ladle into a tundish, which is a small basin at the top of the caster. An operator controls the flow of molten steel from the tundish. The falling steel passes through a mould and begins to take on its final shape. The strand of steel passes through the primary cooling zone, where it forms a solidified outer shell sufficiently strong enough to maintain the strand shape. The strand continues to be shaped and cooled as it curves into a horizontal orientation. After additional cooling, the strand is cut into long sections with a cutting torch or mechanical shears.

Historically, casting was performed by pouring steel into moulds in a batch process that produced large steel ingots. After cooling, the ingots were reheated prior to additional processing.

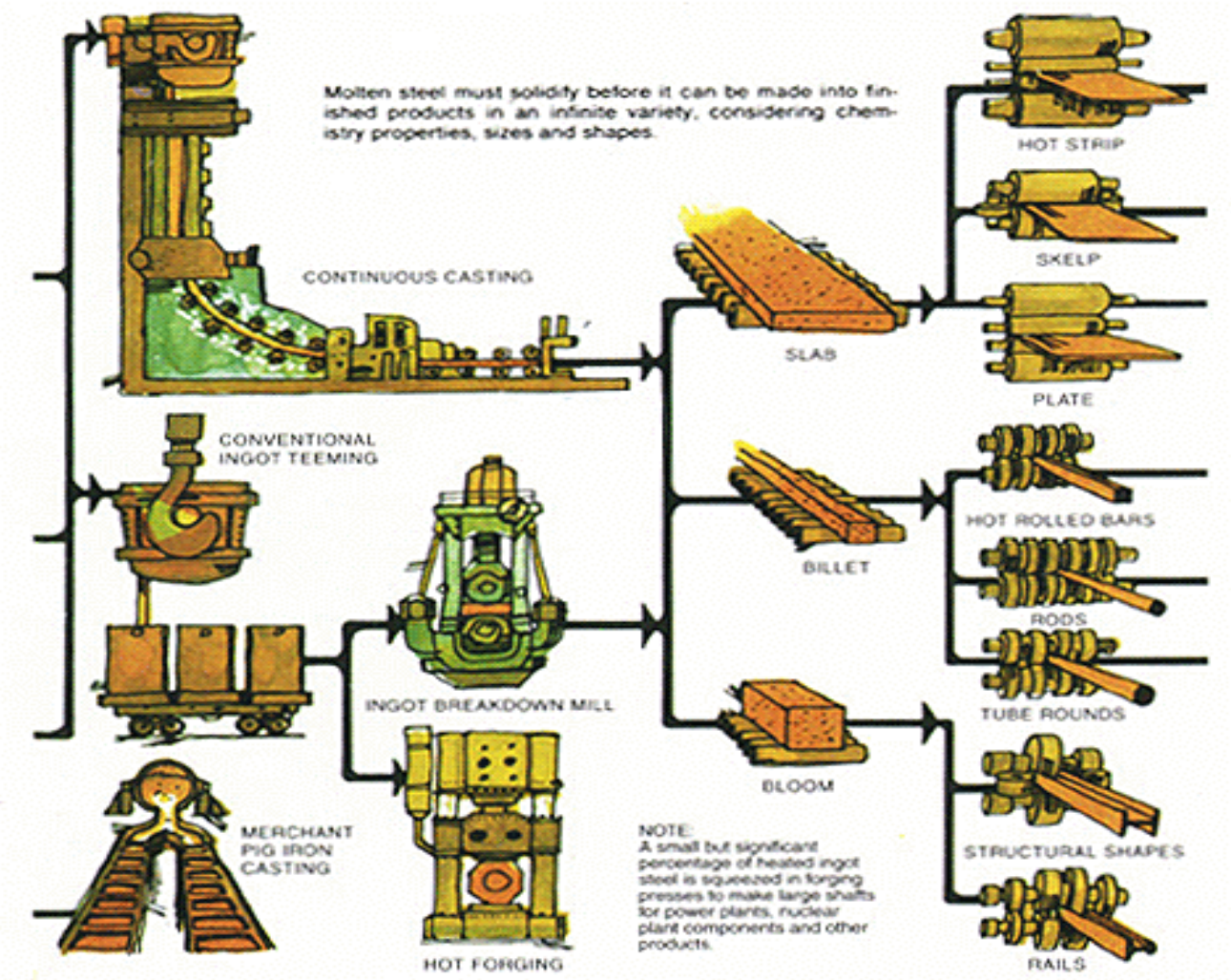
Continuous casting has replaced ingot casting at most steelmaking facilities because it produces large quantities of semi-finished steel closer to their final shape. The resulting steel forms often proceed directly to rolling or forming while retaining significant heat, which reduces downstream reheat costs. Continuous casting achieves dramatic improvements throughout, while reducing reheating and hot rolling costs.

Figure 16: A schematic side view of a continuous caster



An emerging technology for the casting area is strip casting, which uses two rotating casting rolls to directly produce strip of less 2mm. This can reduce, or eliminate in some cases, further downstream processing requirements.

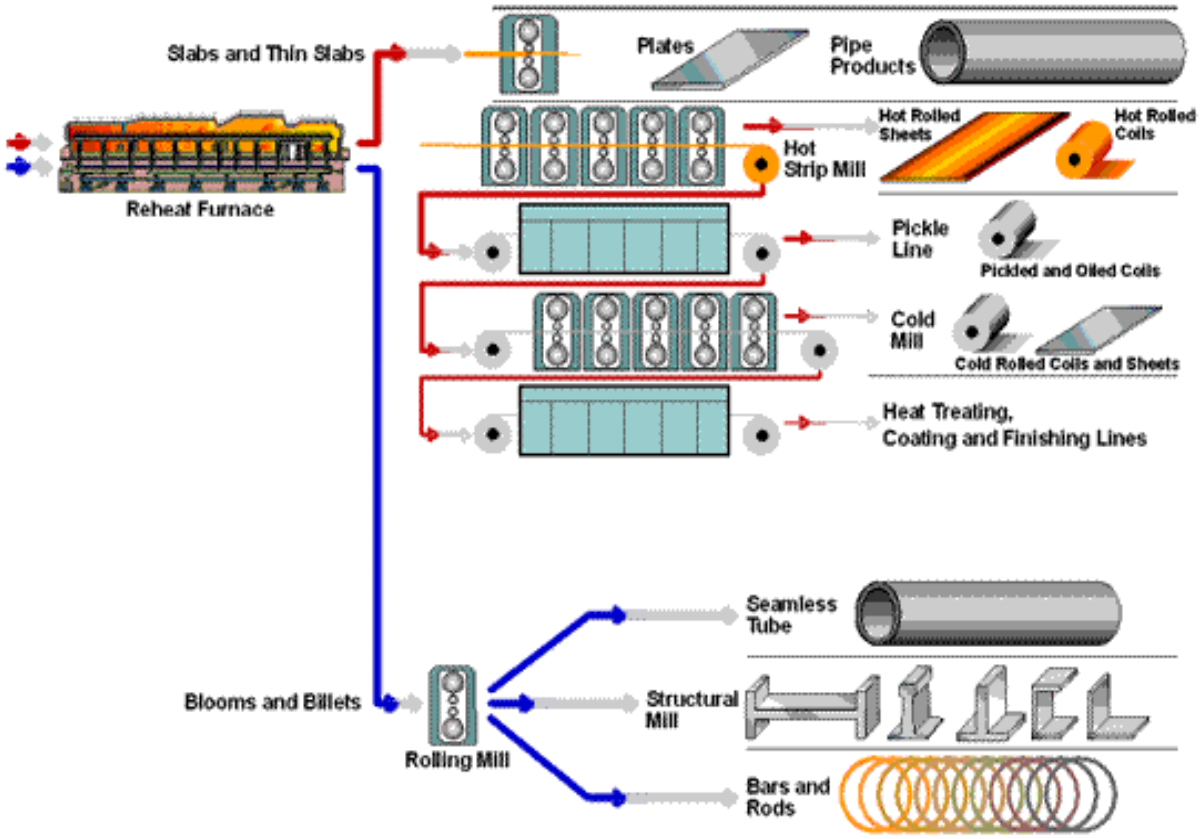
Figure 17: Types of Casting and Downstream Rolling



6. Rolling and Finishing

Rolling and finishing are the processes of transforming semi-finished shapes into finished steel products, which are used by downstream customers directly or to make further goods. Figure 18 summarizes the basic rolling and finishing processes.

Figure 18: Examples of Steel Product Flowlines

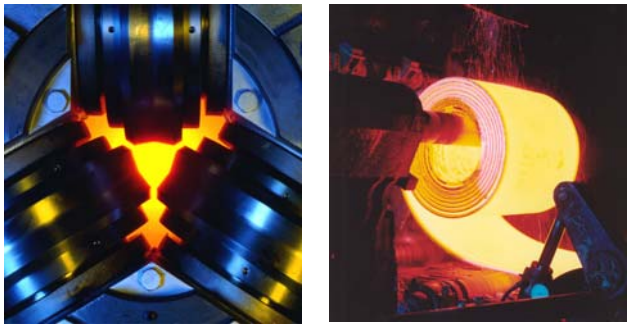


Finishing processes can impart important product characteristics that include: final shape, surface finish, strength, hardness and flexibility, and corrosion resistance. Current finishing technology research focuses on improving product quality, reducing production costs and reducing pollution.

6.1 Rolling and Forming

Rolling and forming semi-finished steel (slabs, blooms or billets) is the mechanical shaping of steel to achieve desired shape and mechanical properties.

Figure 19: Rolling and Forming Processes



Source: http://www.stahl-online.de

Operations can include hot rolling, cold rolling, forming or forging. In hot rolling of steel to strip, for example, steel slabs are heated to over 1,000^{o}C and passed between multiple sets of rollers. The high pressure reduces the thickness of the steel slab while increasing its width and length. After hot rolling, the steel may be cold-rolled at ambient temperatures to further reduce thickness, increase strength (through cold working), and improve surface finish. In forming, bars, rods, tubes, beams and rails are produced by passing heated steel through specially shaped rollers to produce the desired final shape. In forging, cast steel is compressed with hammers or die-presses to the desired shape, with a resultant increase in its strength and toughness.

6.2 Finishing

Finishing of steel is performed to meet specific physical and visual specifications.

Operations include pickling, coating, quenching and heat treatment. Pickling is a chemical treatment, in which rolled steel is cleaned in an acid bath to remove impurities, stains or scales prior to coating.

In coating, cold-rolled sheet steel is coated to provide protection against corrosion and to produce decorative surfaces. Strip coating lines are generally operated continuously, so that in the entry section an endless strip is produced which is divided into coils at the exit section. Coatings may be applied in a hot bath (often zinc-based), in an electro galvanizing bath, or in a bath containing liquid tin.

Quenching, the rapid cooling of steel, is often achieved using water or other liquids. Quenching can increase steel's hardness and is often combined with tempering to reduce brittleness.

The controlled heating and subsequent cooling of steel in heat treatment can impart a range of qualities upon the steel by altering its crystalline structure. Heat treatment is often performed after rolling to reduce the strain that occurs in rolling processes. Annealing, tempering and spheroidizing are three examples of heat treatment, which may be performed in a large batch furnace or in a continuous furnace under a controlled atmosphere (i.e., hydrogen).

Figure 20: Vertical coating line



Figure 21: Galvanized (zinc-coated) steel

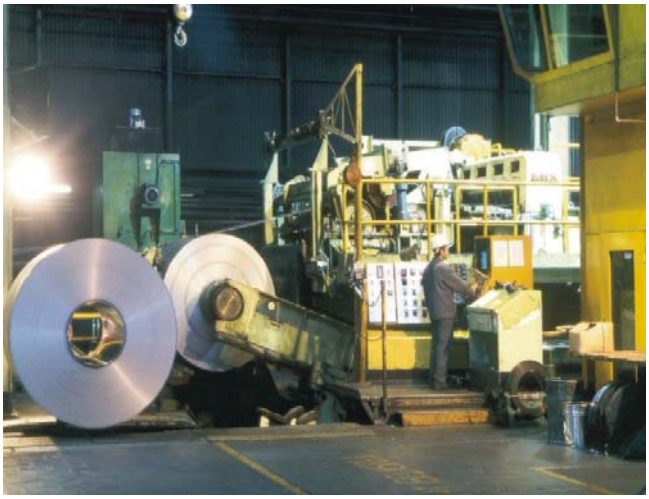


Figure 22: Heat treatment furnace



Source: http://www.stahl-online.de

7. Recycling and Waste Reduction Technologies

Steel production uses large quantities of raw materials, energy and water, while millions of tonnes of steel products reach the end of their useful lives each year.

The steel industry is a recognized leader in developing recycling efforts that minimize the environmental footprint of steel production while reducing costs. Below are some examples in steel recycling, energy efficiency and generation, dust and solids reduction and reuse, and water and gas recycling.

Steel recycling
Steel is the world's most recycled material. In many countries, more than half of all old cars, cans and appliances are recycled. EAF steelmaking is based primarily on the use of scrap steel.

Energy
The use of scrap dramatically reduces energy intensity per tonne of steel produced. The use of combined heat and power (CHP) technology to burn off-gases from steelmaking produces on-site steam and electricity, reducing inefficiencies in generation off-site and distribution across long distances.

Dusts and solids
Coke dust (breeze), iron ore dust and other solids are processed and recycled in steel mills. Slag from ironmaking and steelmaking is used for road construction.

Water and gases
Steelmakers recycle and reuse much of their water. Coke oven gas is recovered and refined for internal use (fuel) and external sales (tars, oils and ammonia). Blast furnace gas is recovered and used to provide heat to the ironmaking process.

Figure 23: Recycling of scrap steel and onsite power generation are an important part of modern steelmaking



8. Common Systems

Steel production requires the heating, shaping and movement of large quantities of materials, in addition to the steelmaking processes discussed previously. These large and essential common systems are described below.

Boilers
Almost all steam for steelmaking is produced in boilers. Steam is used for heating in the finishing process, space heating, and for machine drive. Boiler fuels include by-product gases (e.g., coke oven gas and blast furnace gas), as well as conventional fossil fuels.

Pumps
The large quantities of cooling water and liquids used in steelmaking require large pumps. Pumping systems require large drives and sophisticated maintenance systems.

Figure 24: Ancillary Equipment



Motors
Steelmakers use some of the largest motors in the industrial sector. Electric motors are used in blast furnace fans, rolling mills and numerous other operations. Maintaining motors and minimizing power consumption is a priority for the industry.

Compressed Air
Many control systems and small drives use compressed air. Compressed air systems demand rigorous maintenance to assure efficiency and reliability.

9. General Energy Savings & Environmental Measures

Steel production uses large quantities of raw materials, energy and water. As with any industry, these need to be managed well in order to maximize productivity and profits. As such, improving energy and resource efficiency should be approached from several directions. A strong corporate-wide energy and resource management program is essential. While process technologies described in sections 1 through 8 present well-documented opportunities for improvement, equally important is fine-tuning the production process, sometimes producing even greater savings. In section 9 are some measures concerning these and other general crosscutting utilities that apply to this industry, such as energy monitoring and management systems, cogeneration applications, preventive maintenance practices, slag uses and carbonation processes, and hydrogen production.

Figure 25: Gas Turbine Systems



State-of-the-Art Clean Technologies

1 Agglomeration

1.1 Sintering

1.1.1 Sinter Plant Heat Recovery

Description:
Heat recovery at the sinter plant is a means for improving the efficiency of sinter making. The recovered heat can be used to preheat the combustion air for the burners and to generate high-pressure steam, which can be run through electricity turbines. Various systems exist for new sinter plants (e.g. Lurgi Emission Optimized Sintering (EOS) process) and existing plants can be retrofit[1,2].

Energy/Environment/Cost/Other Benefits:

- Retrofitted system at Hoogovens in the Netherlands:
  - Fuel savings in steam and coke of 0.55 GJ/t sinter, with increased electricity use of 1.5 kWh/tonne sinter[3]
  - NOx, SOx and particulate emissions reduced
  - Capital costs of approximately $3/t sinter[1]
- Wakayama Sintering Plant trial operation in Japan:
  - 110-130 kg/t of sinter recovered in steam
  - 3-4% reduction in coke
  - 3-10% reduction in SOx
  - 3-8% reduction in NOx
  - About 30% reduction in dust
  - Increased productivity, yield, and cold strength
- Taiyuan Steel in Japan:
  - Recovered exhaust heat equaled 15 t/h (or 12,000 KL/year crude oil)
  - SO_2 reduced

Block Diagram or Photo:

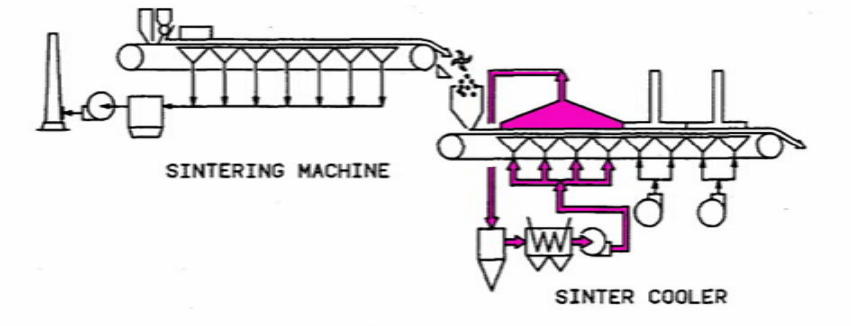


Figure 1.1: Sinter plant heat recovery from sinter cooler [1]

Commercial Status: Mature

Contact information: Sumitomo Metal Industries, Ltd. http://www.sumitomometals.co.jp

[1] Farla, J.C.M., E. Worrell, L. Hein, and K. Blok, 1998. Actual Implementation of Energy Conservation Measures in the Manufacturing Industry 1980-1994, The Netherlands: Dept. of Science, Technology & Society, Utrecht University.
[2] Stelco, 1993. Present and Future Use of Energy in the Canadian Steel Industry, Ottawa, Canada: CANMET.
[3] Rengersen, J., Oosterhuis, E., de Boer, W.F., Veel, T.J.M. and Otto, J. 1995. "First Industrial Experience with Partial Waste Gas Recirculation in a Sinter Plant," Revue de Metallurgie-CIT 3 92 pp. 329-335 (1995).

1.1.2 District Heating Using Waste Heat

Description:
District heating using waste heat in the steel industry is a method for not only saving energy, but also for sharing resources with nearby residential and commercial buildings.

Energy/Environment/Cost/Other Benefits:
- District heating of 5,000 houses, 19 Ktoe/year using sinter cooler waste heat
- Fossil energies such as LPG/LNG are substituted
- Investment $22.3 million

Block Diagram or Photo:

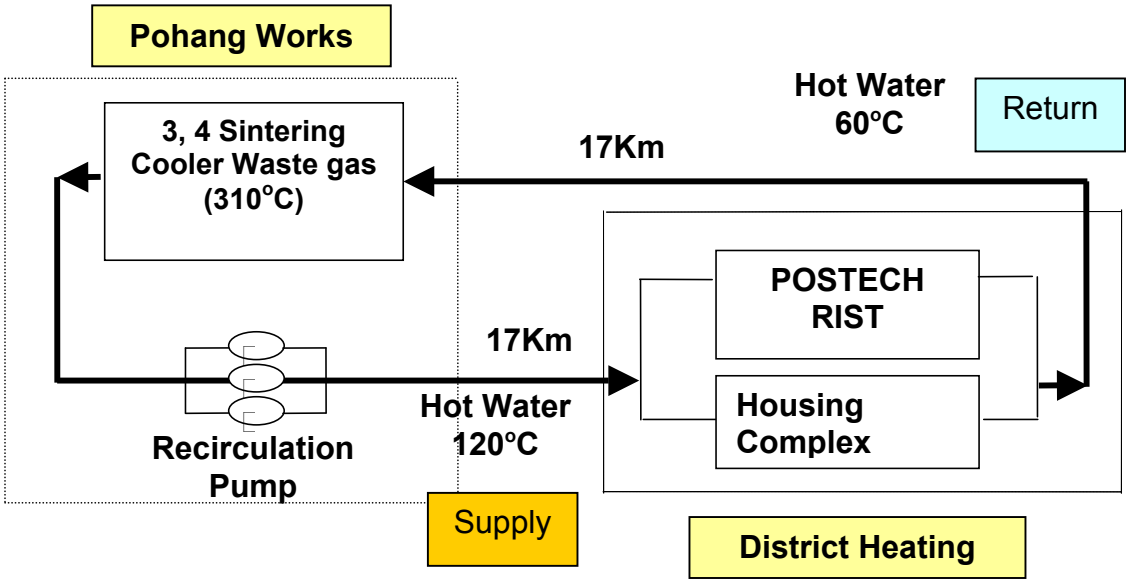


Figure 1.2: Flow diagram of Pohang Steelworks district heating system

Commercial Status: Mature

Contact information:
Yun Sik Jung, Environmental & Energy Dept., POSCO
http://www.posco.co.kr

1.1.3 Dust Emissions Control

Description:
Production increase leads to increased dust generation, thereby increasing particulate emissions. These emissions - off/waste gas – are dust-laden, containing a wide variety of organic and heavy metal hazardous air pollutants (HAPs). Total HAPs released from individual sinter manufacturing operations may exceed ten tons per year[4]. By sending waste gas to Electrostactic Precipitators (ESPs) through negatively charged pipes, the particulate matter (PM) in the waste stream becomes negatively charge. Routing the stream past positively charged plates will then attract and collect the negatively charged PM, thereby producing clean waste gas and increasing the quantity of steam recovery. Course dusts are removed in dry dust catchers and recycled.

Energy/Environment/Cost/Other Benefits:
- Can achieve over 98% efficiency, reducing dust load in off-gas of a typical plant from 3,000 mg/m^3 to about 50 mg/m^3
- ESP removal of fine dust may reduce PM emission levels at sinter plants to about 50 – 150 mg/m^3 depending on actual Specific Dust Resistivity and/or sinter basicity
- ESPs can be installed at new and existing plants
- ESPs cause increased energy consumption of about 0.002 to 0.003 GJ/t sinter
- Kashima Steel Works in Japan installed ESP

Block Diagram or Photo:

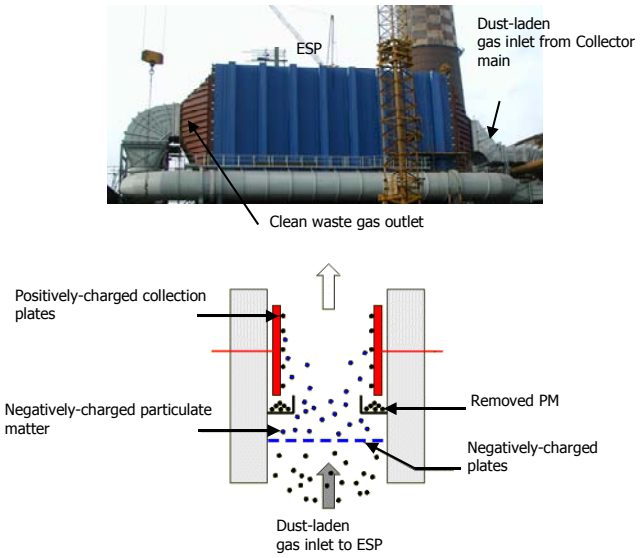


Figure 1.3: Flow diagram and photo of an ESP

Commercial Status: Mature

Contact information:
Sumitomo Metal Industries, Ltd.
http://www.sumitomometals.co.jp

[4] P. J. Marsosudiro 1994. *Pollution Prevention in the Integrated Iron and Steel Industry and its Potential Role in MACT Standards Development,* 94-TA28.02. US Environmental Protection Agency.

1.1.4 Exhaust Gas Treatment through Denitrification, Desulfurization, and Activated Coke Packed Bed Absorption

Description:
Sintering exhaust gas contains SOx, NOx, dust and dioxins. These contaminants are processed, absorbed, decomposed and/or collected as non-toxic by-products to increase the quantity of steam recovery, and improve total fuel savings. Treatment methods to achieve these include: (1) Denitrification Equipment, (2) Desulfurization Equipment, and (3) Activated Coke Packed Bed Absorption.

Energy/Environment/Cost/Other Benefits:
- SOx is absorbed and recovered as useful by-product
- NOx is decomposed to nitrogen, water and oxygen by ammonia
- Dust is collected in activated coke
- Dioxins are collected or absorbed in activated coke and decomposed at 400°C with no-oxygen
- Activated coke absorption removes dioxins to <0.1 ng-TEQ/m^{3}N, dust to <10 mg/m^{3}N, and SOx to <65 % absorbing ratio.

Block Diagram or Photo:

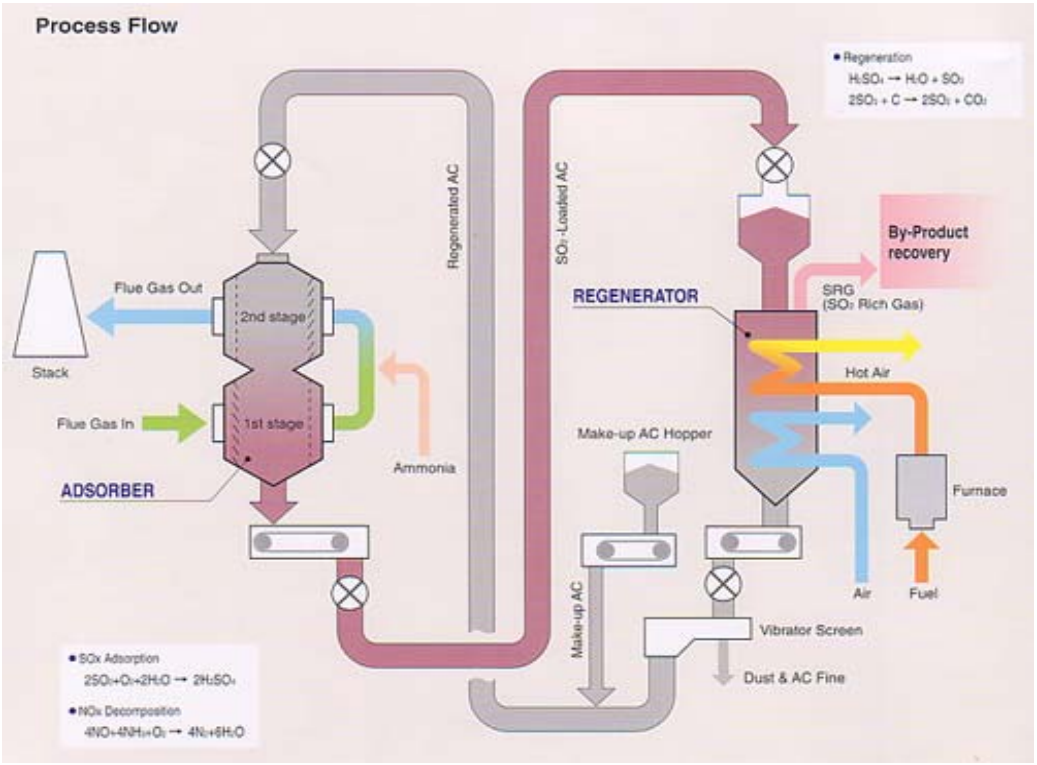


Figure 1.4: Process flow diagram of activated coke method

Commercial Status: Mature

Contact information:

J-Power EnTech, Inc.
http://www.jpower.co.jp/entech

Sumitomo Metal Industries, Ltd.
http://www.sumitomometals.co.jp

1.1.5 Exhaust Gas Treatment through Selective Catalytic Reduction

Description:
SOx and dioxins contained in the sinter flue gas are removed in this process by adding sodium bi-carbonate and Lignite.

NOx is removed by the selective catalytic reduction reaction at around 200~450°C:
$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

For SOx removal the reactions are:
$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$ (T>140°C)
$Na_2CO_3 + 2SO_2 + 1/2O_2 \rightarrow Na_2SO_4 + 2CO_2$

Lignite Injection produces dioxin < 0.2 ng-TEQ/Nm^3.

Energy/Environment/Cost/Other Benefits:
- High SOx and NOx removal efficiency

Block Diagram or Photo:

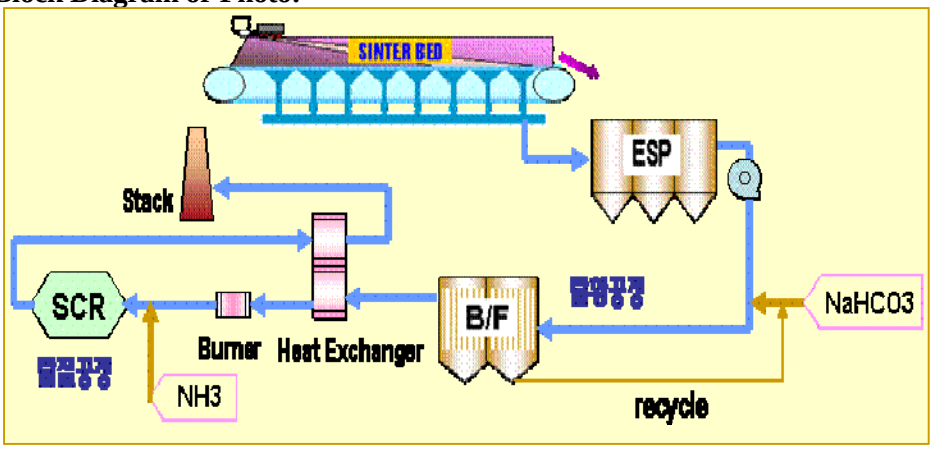


Figure 1.5: NOx and SOx removal using selective catalytic reduction

Commercial Status: Emerging

Contact information:
Mr. Youngdo Jang
Department of Environment & Energy, POSCO
T +82-54-220-5773
ydjang@posco.co.kr

Installation information:
Full-scale facility is being installed in Kwangyang Works; 4 units expected to be completed June 2007.

1.1.6 Exhaust Gas Treatment through Low-Temperature Plasma

Description:
Active radicals of low-temperature plasma remove SOx, NOx and HCl simultaneously. Dioxin also decreased with the addition of Lignite to the process. Reliability and stability have been proven (over five years of operation). Core technology includes full-scale magnetic pulse compressor, stabilizing pulse width and rising time, proper reactor capacity design, and energy saving technology through additives.

Energy/Environment/Cost/Other Benefits:
- Low cost with high pollutants removal efficiency
- Compact - less space required than other technologies
- A commercial scale plant installed at an incinerator in Kwang Works showed a substantial reduction of SOx(>70%), NOx(>95%) and HCl(>99%)
- Dioxin also decreased to less than 0.2 ng-TEQ/Nm3

Block Diagram or Photo:

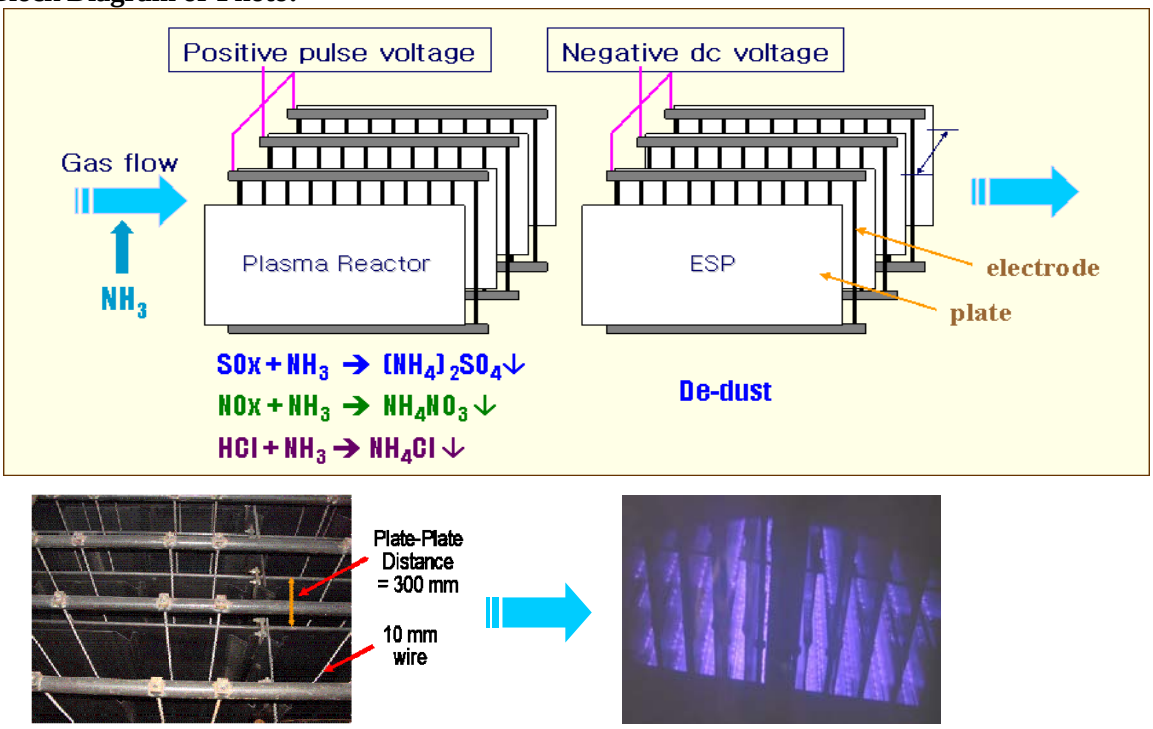


Figure 1.6: NOx and SOx removal using low-temperature plasma

Commercial Status: Emerging

Contact information:
Mr. Youngdo Jang, Department of Environment & Energy, POSCO
T +82-54-220-5773
ydjang@posco.co.kr

Installation information:
Installation of commercial scale plant in 2000 at Kwanyang Works
POSCO plans to adopt above technology at Sinter plant in Pohang Works in about 2010

1.1.7 Improvements in Feeding Equipment

Description:
An additional screen is installed on the conventional sloping chute, which promotes a more desirable distribution of granulated ore on the palette.

Energy/Environment/Cost/Other Benefits:
- The screen with a sloping chute places coarser granulated ore in the lower part of the palette and finer ore on the upper part, which achieves high permeability

Block Diagram or Photo:

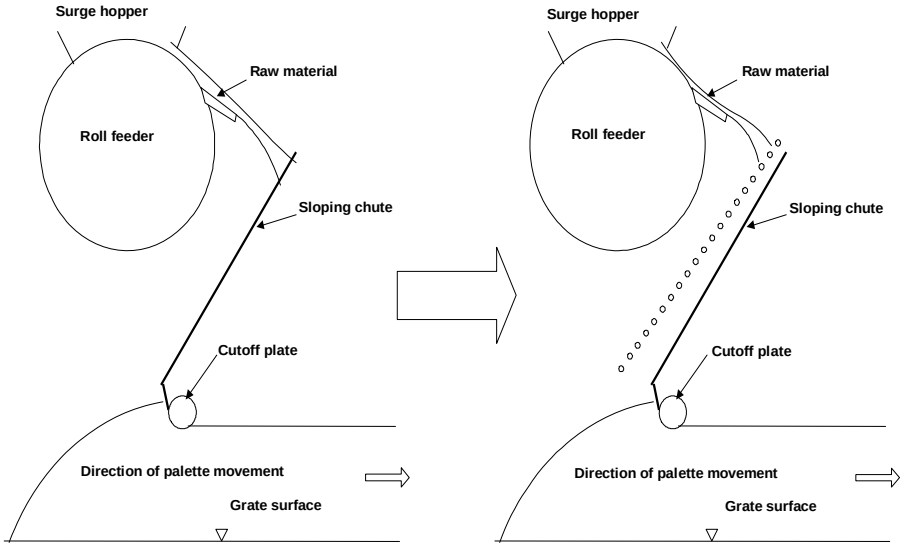


Figure 1.7: Outline of improvements in feeding equipment

Commercial Status: Mature

Contact information:
Sumitomo Metal Industries, Ltd.
http://www.sumitomometals.co.jp

1.1.8 Segregation of Raw Materials on Pellets

Description:
Segregation and granulation reinforcement of raw materials on sintering pellets improve permeability and decrease return rate to sintering pellets, thus increasing productivity and saving energy.

Energy/Environment/Cost/Other Benefits:
- Effective in improving permeability and decrease return rate to sintering pellets
- Increases productivity and saves energy

Block Diagram or Photo:

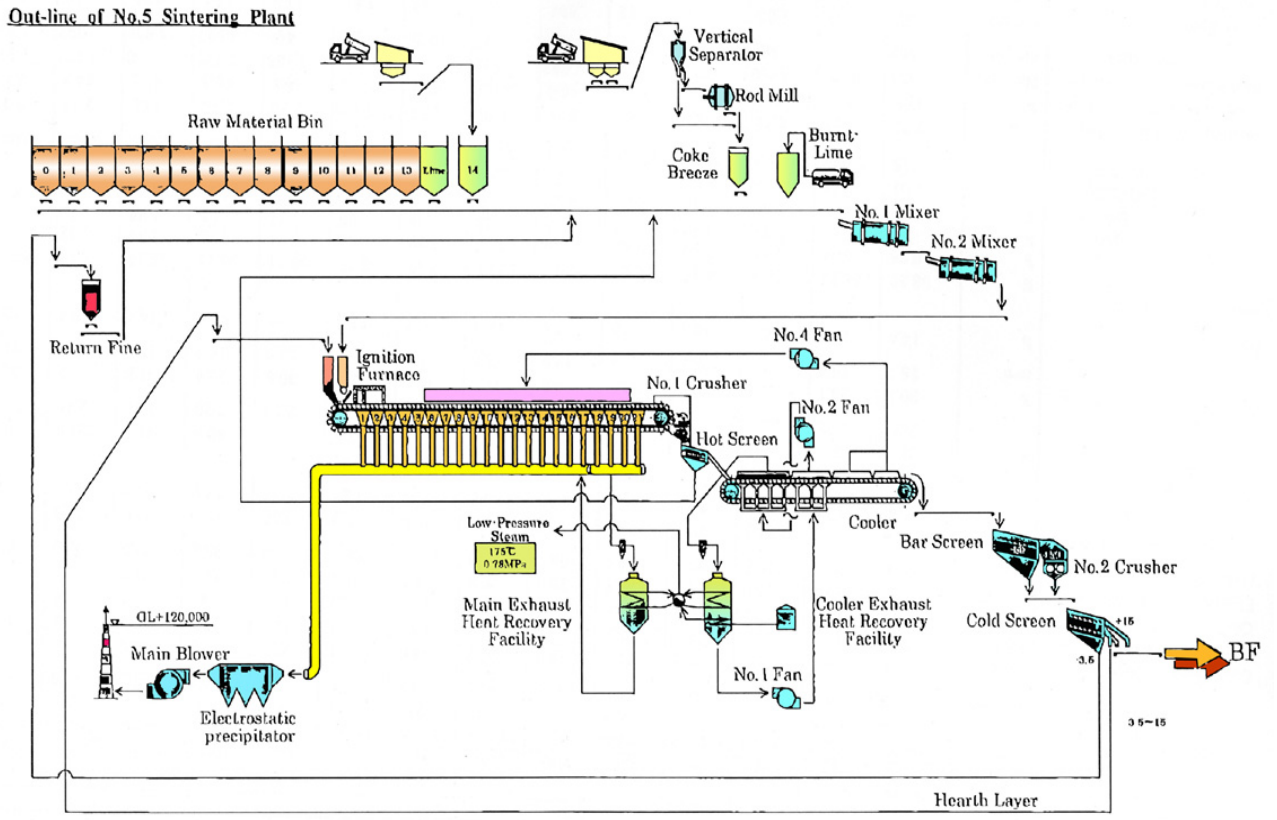


Figure 1.8: Flow diagram of No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries

Commercial Status: Mature

Contact information:

Sumitomo Metal Industries, Ltd.
http://www.sumitomometals.co.jp

JP Steel Plantech Co.
http://www.steelplantech.co.jp

1.1.9 Multi-slit Burner in Ignition Furnace

Description:
Multi-slit burners produce one wide, large stable flame, which eliminates "no flame" areas and supplies minimum heat input for ignition, therefore saving energy.

Energy/Environment/Cost/Other Benefits:
- Total heat input for ignition was reduced by approximately 30% in Wakayama Steel Works of Sumitomo Metals in Japan

Block Diagram or Photo:

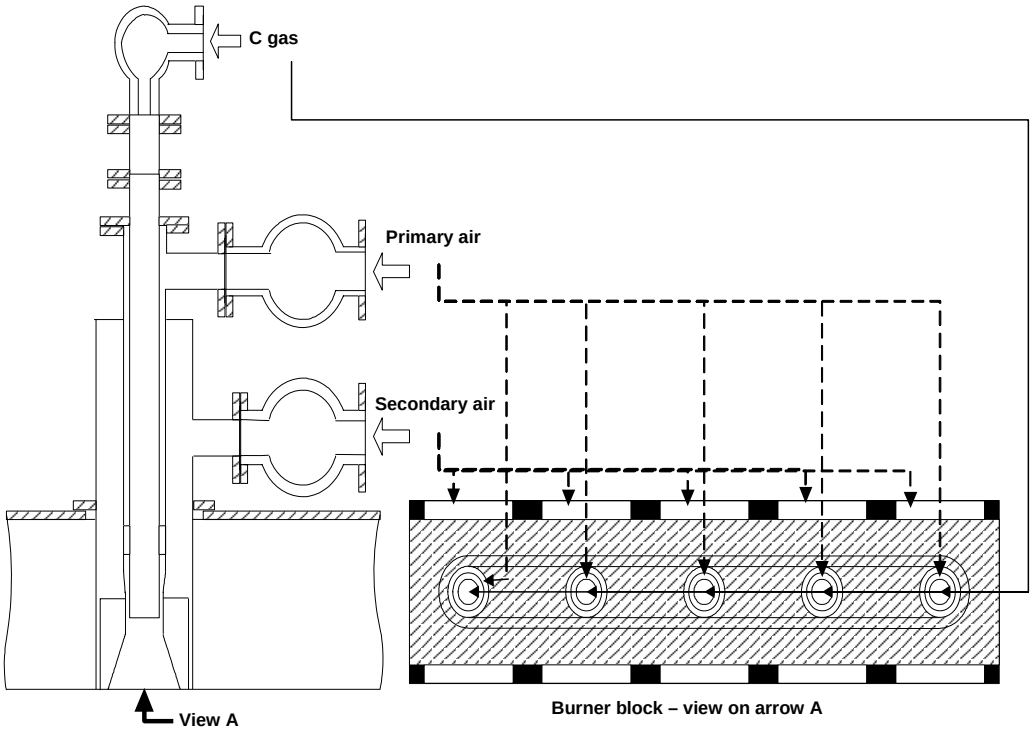


Figure 1.9: Outline of multi-slit burner

Commercial Status: Mature

Contact information:
Sumitomo Metal Industries, Ltd.
http://www.sumitomometals.co.jp

JP Steel Plantech Co.
http://www.steelplantech.co.jp

Installation information:
The burners have been installed in Sumitomo Metals in Japan and many steel works in China and other countries

1.1.10 Equipment to Reinforce Granulation

Description:
A high-speed mixer and a drum mixer (depicted inside the dashed lines in Figure 1.10) are added to the conventional systems for producing granulated ore.

Energy/Environment/Cost/Other Benefits:
- Reinforced granulation at Wakayama Steel works found:
  - Productivity increased from 34.7 to 38.3 t/day m^2
  - Water content increased from 7.0 to 7.3%
  - Granulation rate increased by 45%
  - Permeability increased by 10%
  - Flame front speed increased by 10%
  - Return fine rate decreased less than 1%

Block Diagram or Photo:

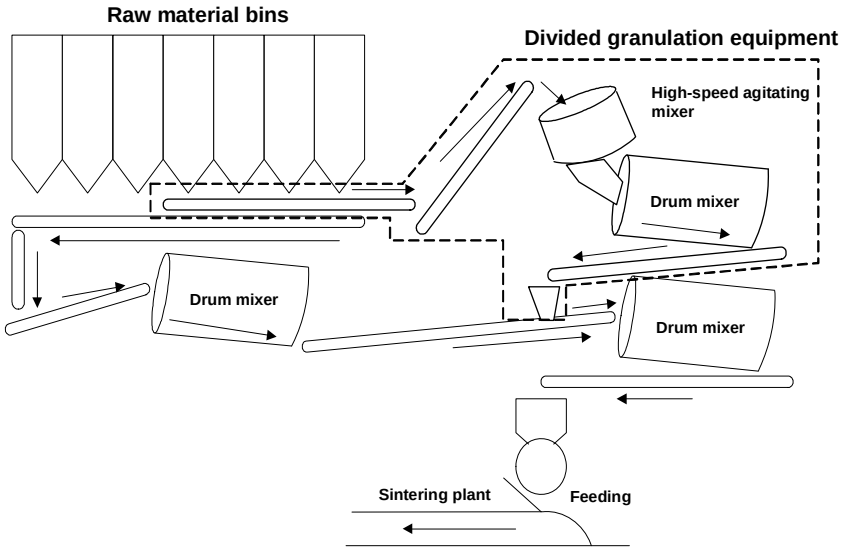


Figure 1.10: Outline of equipment to reinforce granulation (No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

Commercial Status: Mature

Contact information:
Sumitomo Metal Industries, Ltd.
http://www.sumitomometals.co.jp

1.1.11 Biomass for Iron and Steel Making

Description:
Biomass utilization practices for iron and steelmaking are being developed to replace coke breeze in the sintering process. Charcoal has been found to be as effective a fuel and reductant as high rank coals for the bath smelting of iron ores and wood char has been shown to be a suitable replacement for coke breeze in the sintering process, resulting in process improvements and reduction of acid gas levels in process emissions.

Energy/Environment/Cost/Other Benefits:
- Substantial reductions in CO_2 emissions
- Reductions in acid gas emissions
- Improved carburization rates and increased product quality
- Reduced demand for fluxing agents
- Lower slag volume and levels of process wastes
- Higher productivity through use of more reactive carbon

Block Diagram or Photo:



Figure 1.11: Injection of charcoal into a molten iron bath at CSIRO Minerals

Commercial Status: Emerging

Contact information:
Sharif Jahanshahi
http://www.minerals.csiro.au

2 Cokemaking

2.1 Super Coke Oven for Productivity and Environmental Enhancement towards the 21st Century (SCOPE21)

Description:
Super Coke Oven For Productivity and Environmental Enhancement towards the 21st Century (SCOPE21), established through a ten year national program in Japan, replaces existing coke ovens with a new process that expands upon the previous choices for coal sources, while increasing productivity, decreasing environmental pollution, and increasing energy efficiency compared to the conventional cokemaking process.

SCOPE21 has three sub-processes as shown in the block diagram: (1) rapid preheating of the coal charge, (2) rapid carbonization, and (3) further heating of coke carbonized up to medium temperatures. The aim of dividing the whole process into three is to make full use of the function of each process in order to maximize the total process efficiency.

Energy/Environment/Cost/Other Benefits:
- Improved coke strength; Drum Index increased by 2.5 (DI^{150}) over conventional coking
- Reduced coking time from 17.5 hours to 7.4 hours
- Increased potential use of poor coking coal from 20 to 50%
- Productivity increased 2.4 times
- NOx content reduced by 30%
- No smoke and no dust
- Energy consumption reduced by 21%
- Reduction in production cost by 18% and construction cost by 16%

Block Diagram or Photo:

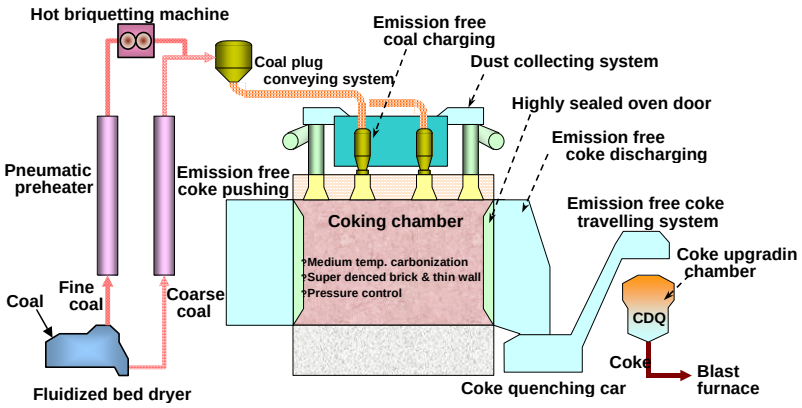


Figure 2.1: Schematic diagram of SCOPE21 process flow

Commercial Status: Mature

Contact Information:
Japan Iron and Steel Federation
http://www.jisf.or.jp/en/index.html

2.2 Coke Dry Quenching

Description:
Coke dry quenching is an alternative to the traditional wet quenching of the coke. It reduces dust emissions, improves the working climate, and recovers the sensible heat of the coke. Hot coke from the coke oven is cooled in specially designed refractory lined steel cooling chambers by counter-currently circulating an inert gas media in a closed circuit consisting of a cooling chamber, s dust collecting bunker, a waste heat boiler, dust cyclones, a mill fan, a blowing device (to introduce the cold air form the bottom) and circulating ducts. Dry coke quenching is typically implemented as an environmental control technology. Various systems are used in Brazil, Finland, Germany, Japan and Taiwan[5], but all essentially recover the heat in a vessel where the coke is quenched with an inert gas (nitrogen). The heat is used to produce steam, which may be used on-site or to generate electricity.

Energy/Environment/Cost/Other Benefits:

- Energy recovered is approximately 400-500 kg steam/t, equivalent to 800-1200 MJ/t coke[6, 7]. Others estimate energy conservation through steam generation (0.48T/T coke).[8] Electricity generation.
- New plant costs are estimated to be $50/t coke, based on the construction costs of a recently built plant in Germany[9]; retrofit capital costs depend strongly on the lay-out of the coke plant and can be very high, up to $70 to $90/GJ saved[10]
- Decreased dust, CO_2 and SOx emissions
- Increased water efficiency
- Better quality coke produced, improved strength of coke by 4%

Block Diagram or Photo:

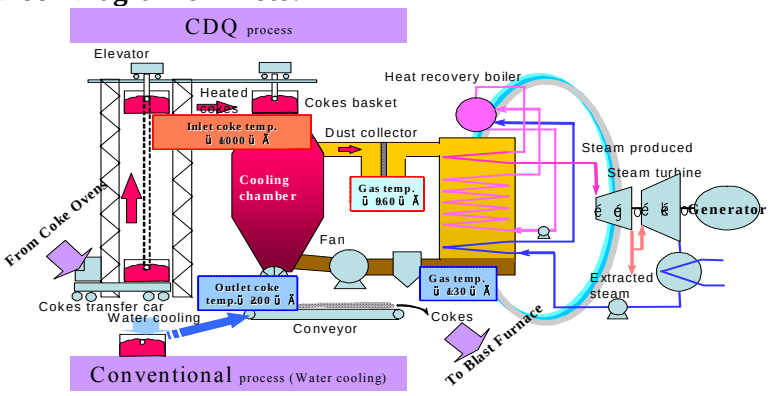


Figure 2.2: Coke quenching process

Commercial Status: Mature

Contact Information: Shijiro Uchida, Nippon Steel Engineering
http://www/nsc-eng.co.jp

Mecon Ltd., India
ranchi@mecon.co.in

Installation information: Visakhapatnam Steel Plant in Andhra Pradesh, India (1989).

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[5] International Iron and Steel Institute, 1993. World Cokemaking Capacity, Brussels, Belgium: IISI.
[6] Stelco, 1993. Present and Future Use of Energy in the Canadian Steel Industry, Ottawa, Canada: CANMET.
[7] Dungs, H. and U. Tschirner, 1994. "Energy and Material Conversion in Coke Dry Quenching Plants as Found in Existing Facilities," Cokemaking International 6(1): 19-29.
[8] Indian delegation additional information provided April 2007.
[9] Nashan, G., 1992. "Conventional Maintenance and the Renewal of Cokemaking Technology," In: IISI, Committee on Technology, The Life of Coke Ovens and New Coking Processes under Development, Brussels: IISI.
[10] Worrell, E., J.G. de Beer, and K. Blok, 1993. "Energy Conservation in the Iron and Steel Industry," in: P.A. Pilavachi (ed.), Energy Efficiency in Process Technology, Amsterdam: Elsevier Applied Science.

2.3 Coal Moisture Control

Description:
Coal moisture control uses the waste heat from the coke oven gas to dry the coal used for coke making. The moisture content of coal varies, but it is generally around 8-9% for good coking coal[11]. Drying further reduces the coal moisture content to a constant 3-5%[12,13], which in turn reduces fuel consumption in the coke oven. The coal can be dried using the heat content of the coke oven gas or other waste heat sources.

Energy/Environment/Cost/Other Benefits:
- Fuel savings of approximately 0.3 GJ/t[8, 9]
- Coal moisture control costs for a plant in Japan were $21.9/t of steel[14]
- Coke quality improvement (about 1.7%)[11]
- Coke production increase (about 10%)[15]
- Shorter cooking times
- Decrease in water pollution (ammonia reduction)

Block Diagram or Photo:

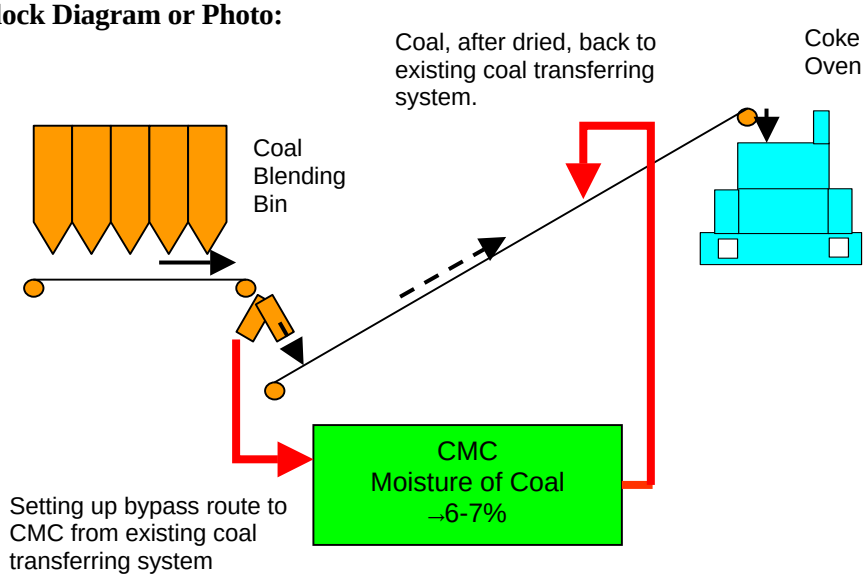


Figure 2.3: Coal moisture control equipment

Commercial Status: Emerging

Contact Information:
Shinjiro Uchida, Nippon Steel Engineering
http://www.nsc-eng.co.jp

---

[11] International Iron and Steel Institute, Committee on Technology, 1982. Energy and the Steel Industry, Brussels, Belgium: IISI.
[12] Stelco, 1993. Present and Future Use of Energy in the Canadian Steel Industry, Ottawa, Canada: CANMET.
[13] Uemastsu, H., 1989. "Control of Operation and Equipment Prevents Coke Oven Damage," Ironmaking Conference Proceedings, Warrendale, PA: Iron and Steel Society.
[14] Inoue, K., 1995. "The Steel Industry in Japan: Progress in Continuous Casting," in *Energy Efficiency Utilizing High Technology: As Assessment of Energy Use in Industry and Buildings*, Appendix A: Case Studies, by M.D. Levine, E. Worrell, L. Price, N. Martin. London: World Energy Council.
[15] Fifth International Iron and Steel Congress (1986). p. 312.

2.4 High Pressure Ammonia Liquor Aspiration System

Description:
The High Pressure Ammonia Liquor Aspiration System (HPALA) in effective for controlling charging emissions in coke oven batteries. In this system, the ammoniacal liquor, which is a by-product in the coke oven, is pressurized to about 35-40 bar and injected through special nozzles provided in the gooseneck at the time of charging. This creates sufficient suction inside the oven, thereby retaining pollutants from being released into the atmosphere. The system consists of high-pressure multistage booster pumps, sturdy pipe-work, specially designed spray nozzles, suitable valves and control instruments.

Energy/Environment/Cost/Other Benefits:
- Emissions control
- High reliability and simplicity of operation
- Low operational and maintenance costs
- Appreciable saving in quantity of process steam required and increased raw gas yield/by-products generation, due to elimination of gases vented into the atmosphere

Block Diagram or Photo:

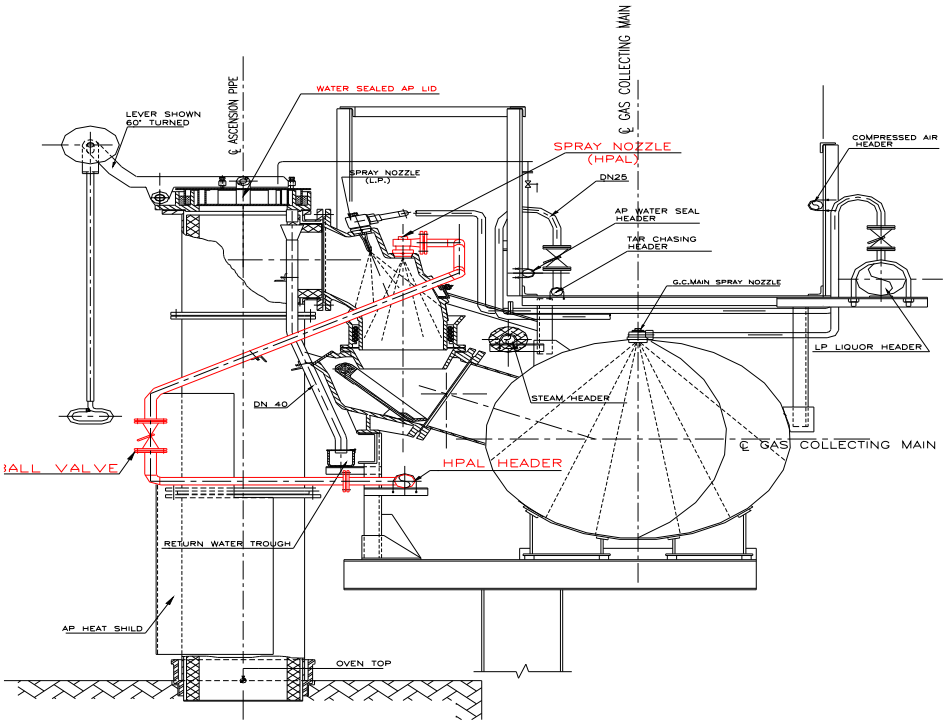


Figure 2.4: Typical installation of HPALA system in Gooseneck for on-main charging

Commercial Status: Mature

Contact Information:
Consultant:
Mecon Ltd.
ranchi@mecon.co.in

Suppliers:
Nozzle: Lechler India (Pvt.) Ltd., Thane, Maharashtra, India
Pumps: Sulzer Pumps India Ltd., Thane, Maharashtra, India
Kirloskar Brothers Ltd., Pune, India

Installation information:
SAIL plants including: Rourkela Steel Plant, Bhilai Steel Plant, and Bokaro Steel Ltd., all in India.

2.5 Modern Leak-proof Door

Description:
Coke oven leaking doors can be a major source of pollution. With the advent of recovery type ovens, the design of oven doors has gone through a process of evolution, beginning from luted doors to the present generation self-regulating zero-leak doors. The important features of the leak-proof door include: (1) a thin stainless steel diaphragm with a knife edge as a sealing frame built in between the door body and the brick retainer, (2) spring loaded regulation on the knife edge for self-sealing, (3) provision for air cooling of the door body, and (4) large size gas canals for easier circulation of gas inside oven.

Energy/Environment/Cost/Other Benefits:
- Minimization of door leakage
- Regulation free operation
- Longer life due to less warping of the air cooled door body
- Reduced maintenance frequency
- Conventional doors can be replaced by leak-proof doors without altering battery/door frame design

Block Diagram or Photo:

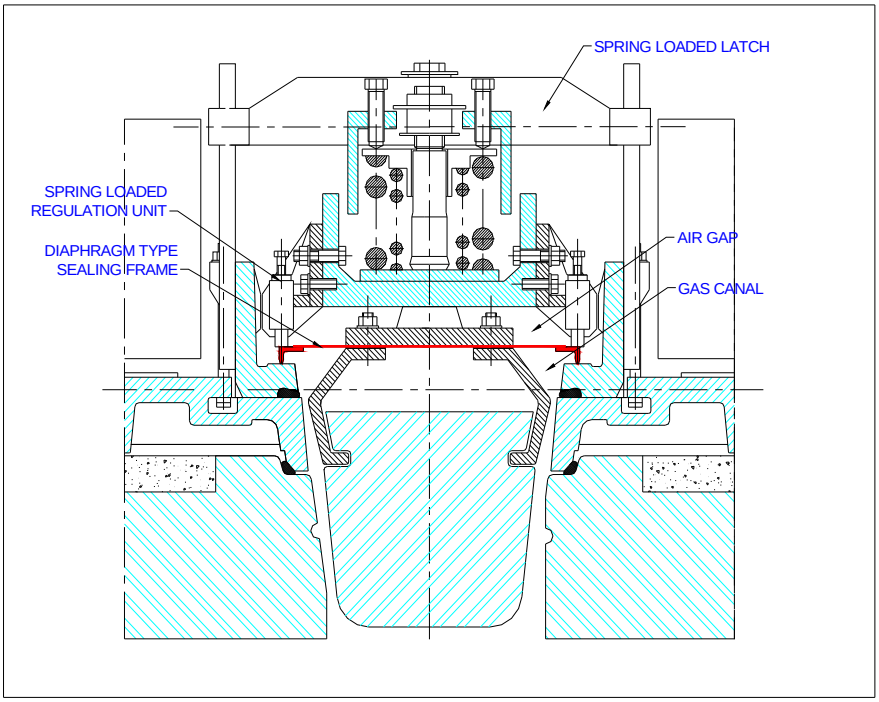


Figure 2.5: Cross-section of modern leak-proof door

Commercial Status: Mature

Contact Information:
Consultant: Mecon Ltd., India
ranchi@mecon.co.in

Suppliers:
Simplex Castings, Ltd., Bhilai, India
BEKEY Engineering Ltd., Bhilai, India

Installation information:
TISCO, Durgapur Steel Plant, Bhilai Steel Plant, and Vishakhapatnam Steel Plant, all in India.

2.6 Land Based Pushing Emission Control System

Description:
The smoke and fumes produced during the pushing of red hot coke contains a huge amount of coke dust (estimated at 11% of the total pollution in the coke oven). Land based pushing emission control systems mitigate this pollution. It consists of three parts: (1) a large gas suction hood fixed on the coke guide car and moving with the coke guide, sending fumes to the coke side dust collecting duct; (2) the dust collection duct; and (3) the final equipment for smoke purification on the ground (ground piping, accumulator cooler, pulse bag dust collector, silencer, ventilation unit, stack, etc). The large amount of paroxysmal high-temperature smoke produced during coke discharging is collected under the hot float fan into the large gas suction hood installed in the coke guide car, and enters the dust collection duct through the other equipment. The air is dissipated into the atmosphere after purification by the pulse dust collector and after being cooled by the accumulator cooler. The total de-dusting system is controlled by PLC.

Energy/Environment/Cost/Other Benefits:
- Elimination of pushing emission up to the large extent

Block Diagram or Photo:

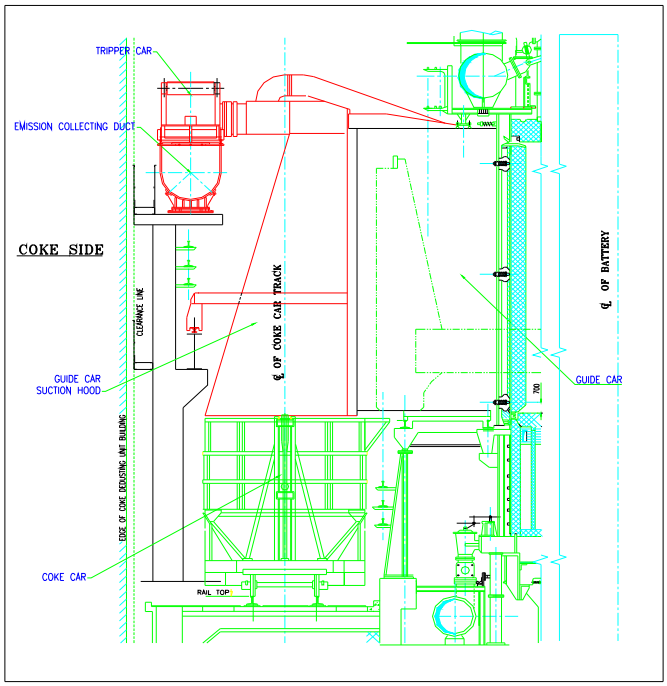


Figure 2.6: Land based pushing emission control system

Commercial Status: Emerging

Contact Information:

Consultant:	Suppliers:
Mecon Ltd., Ranchi, India	Thermax India
ranchi@mecon.co.in	Pune, BEC, India

Installation information:
New projects at COB no. 4 of Vishakhapatnam Steel Plant, India, Bhushan Steel & Strips Ltd. in Angul, Orissa, India, Jindal Stainless in Duburi, Orissa, India, and Jindal South West in Karnataka, India.

3 Ironmaking

3.1 Blast Furnace Ironmaking

3.1.1 Top Pressure Recovery Turbine

Description:
Top Pressure Recovery Turbine (TRT) is a power generation system, which converts the physical energy of high-pressure blast furnace top gas into electricity by using an expansion turbine. Although the pressure difference is low, the large gas volumes make the recovery economically feasible. The key technology of TRT is to secure the stable and high-efficiency operation of the expansion turbine in dusty blast gas conditions, without harming the blast furnace operation.

Energy/Environment/Cost/Other Benefits:
- Generates electric power of approximately 40-60 kWh/t pig iron
- Japanese Integrated Steel Works:
  - Generates more than 8% of electricity consumed in Japanese ironworks (about 3.33 TWh)
- Excellent operational reliability, abrasion resistant
- Suitable for larger furnaces and higher temperature gases compared to Bag filter systems
- Wet TRT System (US):
  - Typical investments of about $20/t power recovery of 30 kWh/t hot metal[16]
  - No combustion of BF gas
- Dry TRT System, e.g., Venturi Scrubber- Electrostatic Space Clear Super (VS-ESCS):
  - Lower water consumption compared with wet type
  - Raises turbine inlet temperature, increasing power recovery by about 25-30%[17]
  - More expensive than wet type, $28/t hot metal[2]

Block Diagram or Photo:

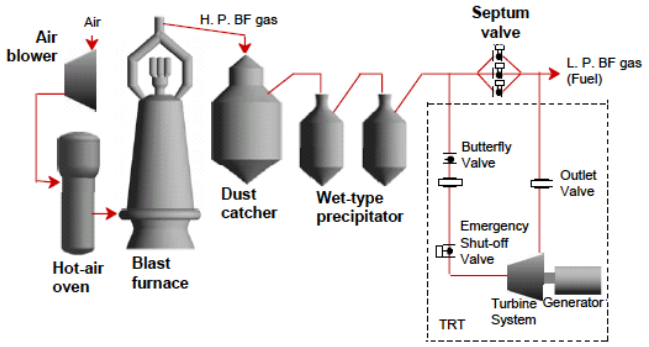


Figure 3.1: Flow diagram of TRT system (wet type)

Commercial Status: Mature

Contact information:
Kawasaki Heavy Industries, Ltd.
http://khi.co.jp/products/gendou/ro/ro_01.html

Shinjiro Uchida, Nippon Steel Engineering
http://www.nsc-eng.co.jp

Mitsui Engineering & Shipbuilding Co., Ltd.
http://mew.co.jp/business/english/energy/energy_10.html

[16] Inoue, K., 1995. "The Steel Industry in Japan: Progress in Continuous Casting," in *Energy Efficiency Utilizing High Technology: As Assessment of Energy Use in Industry and Buildings*, Appendix A: Case Studies, by M.D. Levine, E. Worrell, L. Price, N. Martin, London: World Energy Council.
[17] Stelco, 1993. *Present and Future Use of Energy in the Canadian Steel Industry,* Ottawa, Canada: CANMET.

3.1.2 Pulverized Coal Injection (PCI) System

Description:
Pulverized coal injection replaces part of the coke used to fuel the chemical reaction, reducing coke production, thus saving energy. The increased fuel injection requires energy from oxygen injection, coal, and electricity and equipment to grind coal. The coal replaces the coke, but coke is still used as a support material in the blast furnace (BF). The maximum injection depends on the geometry of the BF and impact on the iron quality (e.g., sulfur).

Energy/Environment/Cost/Other Benefits:
- Reduces emissions of coke ovens
- Increased costs of oxygen injection and maintenance of BF and coal grinding equipment offset by lower maintenance costs of existing coke batteries and/or reduced coke purchase costs, yielding a net decrease in operating and maintenance costs, estimated to be $15/t[18], but a cost savings of up to $33/t are possible, resulting in a net reduction of 4.6% of costs of hot metal production[19]
- Decreased frequency of BF relining
- Improved cost competitiveness with cost reduction of hot metal
- Investment of coal grinding equipment estimated at $50-55/t coal injected[20]
- High reliability and easy operation
- Increased productivity
- Uniform transfer of pulverized coal
- No moving parts in injection equipment
- Even distribution to Tuyeres

Block Diagram or Photo:

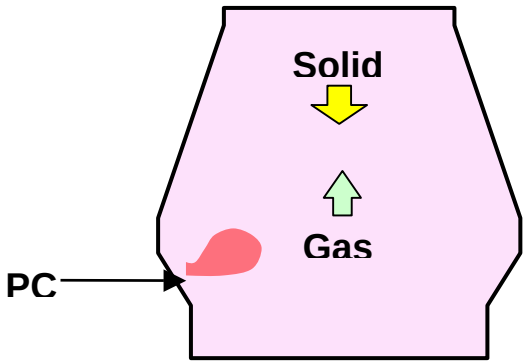


Figure 3.2: Diagram of PCI System

Commercial Status: Mature

Contact information:
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http://www.nsc-eng.co.jp

trade@cisri.com.cn

www.danieli-corus.com
www.claudiuspeters.com
paulwurth@paulwurth.com
metals-mining@siemens.com

[18] International Energy Agency, 1995. *Energy Prices and Taxes, First Quarter 1995*, Paris: IEA.
[19] Oshnock, T.W., 1995a. "Pulverized Coal Injection for Blast Furnace Operation, Part IV," *Iron & Steelmaking* **22**(2): 41-42.
[20] Farla, J.C.M., E. Worrell, L. Hein, and K. Blok, 1998. *Actual Implementation of Energy Conservation Measures in the Manufacturing Industry 1980-1994,* The Netherlands: Dept. of Science, Technology & Society, Utrecht University

3.1.3 Blast Furnace Heat Recuperation

Description:
Recuperation systems, e.g., Hot Blast Stove, BFG Preheating System, etc., are used to heat the combustion air of the blast furnace. The exit temperature of the flue gases, approximately 250^0C, can be recovered to preheat the combustion air of the stoves.

Energy/Environment/Cost/Other Benefits:
- Hot Blast Stove:
  - Fuel savings vary between 80-85 MJ/t hot metal[21, 22]
  - Costs are high and depend strongly on the size of the BF, estimated at $18-20/(GJ saved), equivalent to $1.4/t hot metal[7]
  - Efficient hot blast stove can run without natural gas
- BFG Preheating System at POSCO in Korea:
  - Anti-corrosion technology with high surface temperatures
  - Economic recovery for low to medium temperature grade heat
  - 102 kcal/kWh reduction in fuel input; thermal efficiency increase of 3.3%
  - Energy savings of 3-5% for boiler, with payback period of within 1.5 years
  - Proven reliability and stability for more than 10 years of operation

Block Diagram or Photo:

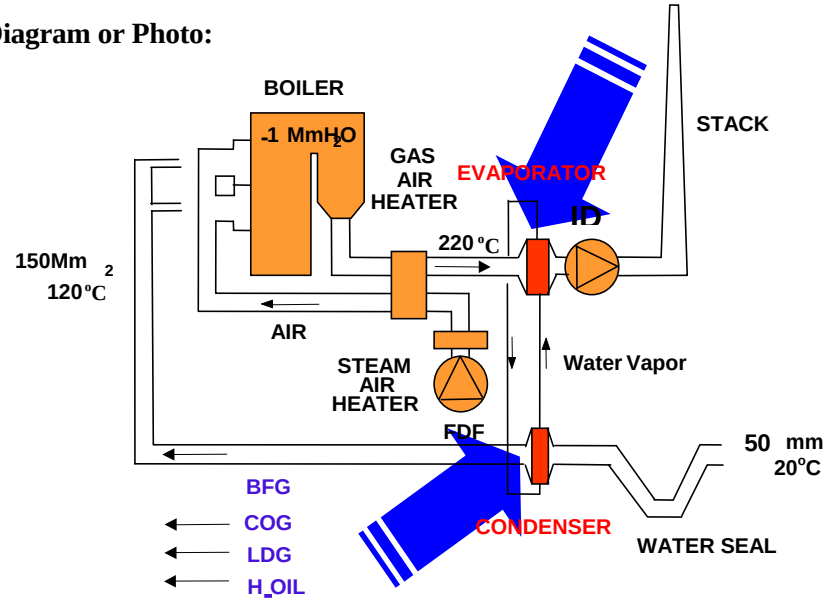


Figure 3.3: BFG Preheating System

Commercial Status: Emerging

Contact information:
Yun Sik Jung, Pohang Works, POSCO
+82-54-220-4579
yswilly@posco.co.kr
http://www.posco.co.kr

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[21] Farla, J.C.M., E. Worrell, L. Hein, and K. Blok, 1998. *Actual Implementation of Energy Conservation Measures in the Manufacturing Industry 1980-1994*, The Netherlands: Dept. of Science, Technology & Society, Utrecht University
[22] Stelco, 1993. *Present and Future Use of Energy in the Canadian Steel Industry*, Ottawa, Canada: CANMET.

3.1.4 Improve Blast Furnace Charge Distribution

Description:
Charging systems of old blast furnaces and new blast furnaces are being retrofitted or equipped with the Paul Wurth Bell Less Top (BLT) charging systems. Input materials like coke and sinter are screened before charging. Proper distribution of input materials improves the coking rate and increases production.

Energy/Environment/Cost/Other Benefits:
- Increased fuel efficiency
- Reduced emissions
- Increased productivity
- Improved coking rate

Block Diagram or Photo: None provided

Commercial Status: None provided

Contact information:
Paul Wurth Bell Engineering and Technology
http://www.paulwurth.com/
paulwurth@paulwurth.com

TOTEM Co. Ltd
totem@totem-engineering.com

Siemens AG
http://www.siemens.com/index.jsp
metals-mining@siemens.com

Consultant: bf@ranchi.mecon.co.in

3.1.5 Blast Furnace Gas and Cast House Dedusting

Description:
When blast furnace gas (BFG) leaves the top of the furnace it contains dust particles. Dust particles are removed either with a conventional wet type dedusting system or a dry type dedusting system. Both systems consist of a gravity dust catcher to remove dry large particulate from the BFG stream. The wet fine particulate is then removed in wet type dedusting with a two-stage Venturi or Bisholff scrubber, whilst dry type dedusting does not require water scrubbing and instead employs an electro-precipitator or a bag filter to clean the BFG.

Energy/Environment/Cost/Other Benefits:
- Dust catcher removes about 60% of particulate from BFG[23]
- Wet Type Dedusting:
  - Produces gas containing less than 0.05 grams/m^3 of particulate[24]
  - Pressure and noise control devices not necessary
- Dry Type Dedusting:
  - 30% increase in power generated with dry-type TRT system compared to wet type dedusting
  - 7-9 Nm^3/tHM reduction in recirculated water consumption, of which 0.2m^3 is fresh water
  - Eliminates generation of polluted water and slurry
  - Improved gas cleanness with dust content of <5mg/Nm^3
  - 50% less occupied land area than wet type dedusting
  - Minimized investment cost and accelerates project construction, as only accounts for 70% in investment compared to wet type dedusting

Block Diagram or Photo:

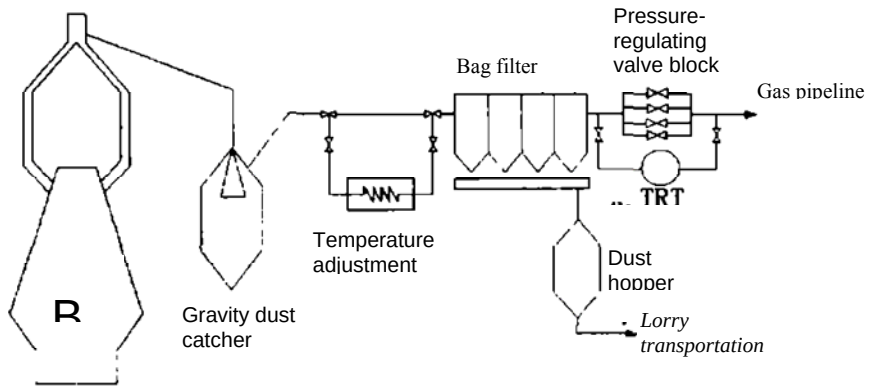


Figure 3.4: BFG Dry Type Dedusting System

Commercial Status: Emerging

Contact information:
Laiwu Iron & Steel Corp (Group)
Kakogawa Works, Kobe Steel

[23] US Department of Energy, Office of Industrial Technologies, 2000. *Energy and Environmental Profile of the US Iron and Steel Industry,* Washington, DC: US DOE, OIT.
[24] US Environmental Protection Agency. 1995b. *Compilation of Air Pollutant Emission Factors, Vol. I: Stationary Point and Area Sources, IAP-42*, 5th ed.

3.1.6 Cast House Dust Suppression

Description:
The primary source of blast furnace particulate emissions occurs during casting. Molten iron and slag emit smoke and heat while traveling from the taphole to ladle, or the slag granulator to pit. The cast house dust suppression system is designed to contain emissions. "Dirty" air is drawn through the baghouse, which contains separate collection chambers each with a suction fan, and is then exhausted into the atmosphere. The system has multiple collection hoods: overhead hoods above each taphole and skimmer, and below-floor hoods above each tilting spout.

Energy/Environment/Cost/Other Benefits:
- Individual baghouse collection chambers can be shut down without affecting operation

Block Diagram or Photo:

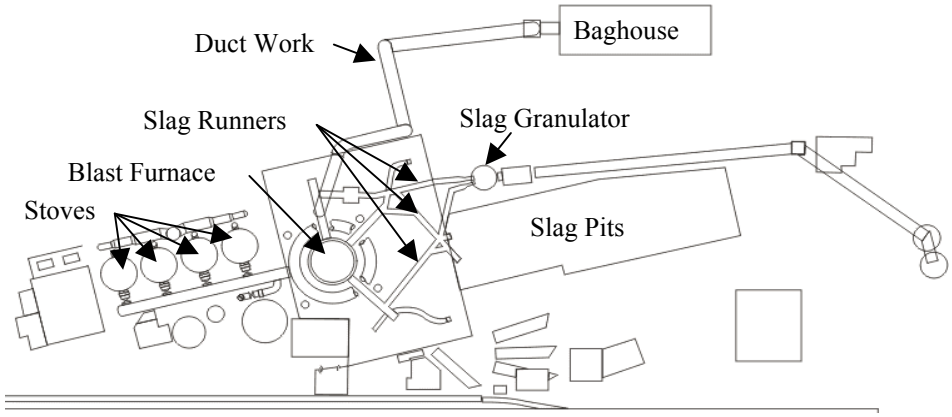


Figure 3.5: Cast house dust suppression system

Commercial Status: Mature

Contact information:
None provided

3.1.7 Slag Odor Control

Description:
Slag odor can be reduced significantly by water granulation. Circulating water is used for blowing (with cooling tower installed).

Energy/Environment/Cost/Other Benefits:
- In water granulation, average slag odor generated is 14 g-S/min, compared to 228 g-S/min found immediately after slag discharge at 800^0C.

Block Diagram or Photo:

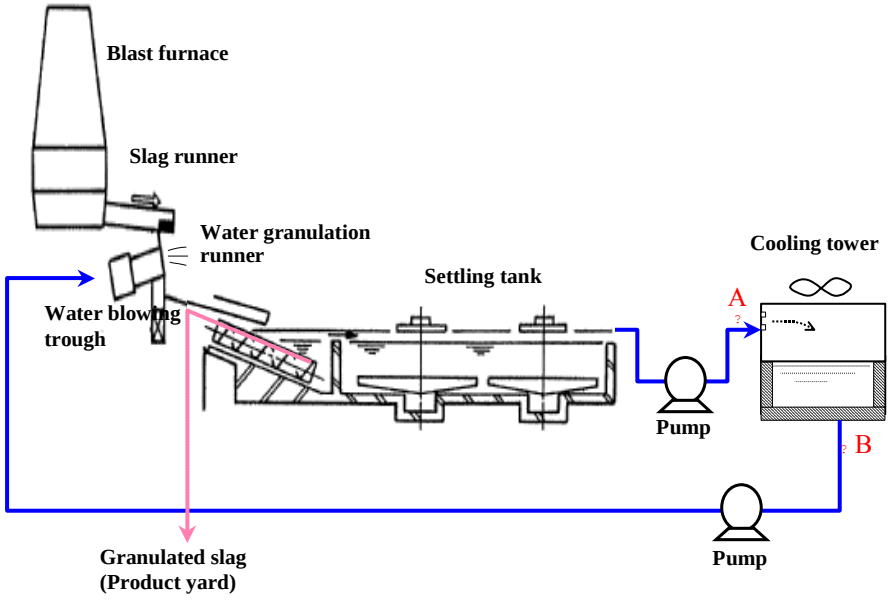


Figure 3.6: Water granulation devise flow (No.1 Blast Furnace at Kakogawa Works, Kobe Steel)

Commercial Status: Mature

Contact information:
Kakogawa Works, Kobe Steel

3.2 Direct Reduction

No technologies available at the time of publication. Technologies will be added in the future as appropriate.

3.3 Direct Ironmaking

3.3.1 Smelting Reduction Processes

Description:
Smelting reduction processes, including Aumelt Ausiron®, HIsmelt®, CCF, DIOS and COREX, involve the pre-reduction of iron ore by gases coming from a hot bath. The pre-reduced iron is then melted in the bath, and the excess gas produced is used for power generation, production of direct reduced iron (an alternative iron input for scrap), or as fuel gas. In this way, smelting reduction eliminates the need for coke and sintering, and future processes will also eliminate ore preparation.

Energy/Environment/Cost/Other Benefits:

- Low capital and operating costs:
  - 5-35% below production cost of conventional route[25]
  - Direct use of iron ore fines/steel plant dusts and thermal coals
  - No coke ovens, sinter plants, blending yards
  - Single furnace with direct waste energy recovery
- Low environmental impact:
  - No coke-oven or sinter plant emissions, and reduced CO_2, SO_2 and NOx, no production of dioxins, furans, tars or phenols
  - Recycling of steel plant dusts and slag, making effective uses of coal energy
- High quality iron product, with impurities reported to the slag not the metal
- Greater flexibility in the range of raw materials accepted, including steel plant wastes and high phosphorous ores

Block Diagram or Photo:

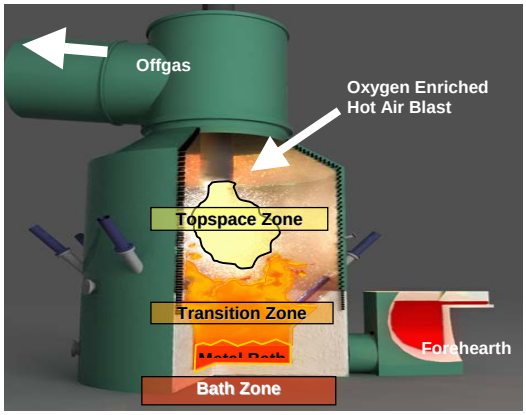


Figure 3.7: Outline of Smelting Reduction Process

Commercial Status: Emerging

Contact information:

HIsmelt Corporation
http://www.hismelt.com.au

Ausmelt Limited Pty. Ltd.
http://www.ausmelt.com.au

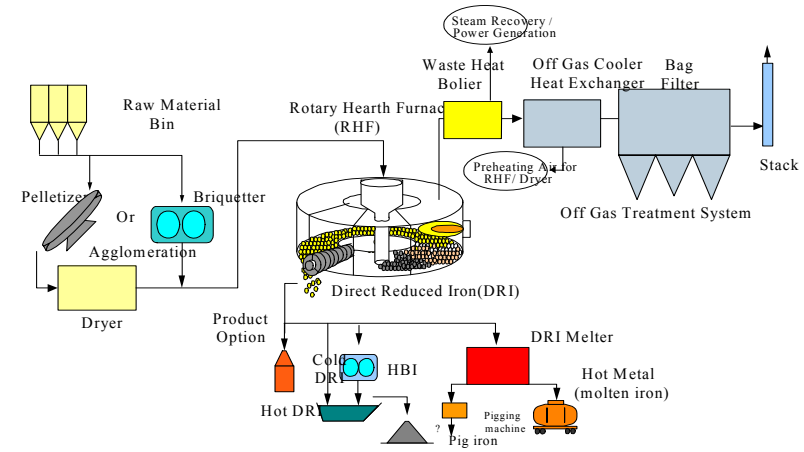
[25] De Beer, J., K. Block, E. Worrell. 1998a. "Future Technologies for Energy-Efficient Iron and Steelmaking." In *Annual Review of Energy and the Environment.* Vol. 23: 123-205; 1998b. "Long-term energy-efficiency improvements in the paper and board industry." In *Energy*. 23 (1): 21-42.

3.3.2 Direct Reduction Processes

Description:
Direct reduced iron (DRI) is produced through the reduction of iron ore pellets below the melting point of the iron. This is achieved with either natural gas (MIDREX® process) or coal-based (FASTMET® process) reducing agents. The DRI produced is mainly used as a high quality iron input in electric arc furnace (EAF) plants.

Energy/Environment/Cost/Other Benefits:
- Pre-treatment of raw material not necessary
- Eliminates coke oven
- Low capital and operating costs
- FASTMET® Process:
  - Faster speed and lower temperatures for reduction reaction
  - Fuel useage can be reduced;not necessary to recover and reuse exhaust gases as secondary combustion of close to 100% is achieved in the rotary hearth furnace
  - Low heat loss, as reduced iron is fed to the melting furnace for hot metal production without cooling
  - Low emissions – 0.3-1.5 kg/THM NOx, 2.4 kg/THM SOx, and 0.3 kg/THM PM_{10} (-particulate matter less than 10.0 microns in diameter)
  - Energy consumption is 12.3 GJ/t-hot metal less than mini blast furnace; CO_2 is reduced by 1241 kg/t hot metal

Block Diagram or Photo:



Note :
* Agglomeration method will be decided depending on raw material conditions.
* Waste heat bolier is optional.

Figure 3.8: FASTMET® Process Flow

Commercial Status: None provided

Contact information:
Japan Iron and Steel Federation
http://www.jisf.or.jp/en/index.html

3.3.3 ITmk3 Ironmaking Process

Description:
ITmk3® uses the same type of rotary hearth furnace (RHF) as the FASTMET® process[26]. The process uses low-grade iron ore and coal (but other feedstocks can be used as a supplement) to produce iron nuggets of superior quality to direct reduced iron (97% iron content), but similar to pig iron. The mixing, agglomeration, and feeding steps are the same, but the RHF is operated differently. In the last zone of the RHF, the temperature is raised, thereby melting the iron ore and enabling it to easily separate from the gangue. The result is an iron nugget containing iron and carbon, with almost no oxygen or slag.

Energy/Environment/Cost/Other Benefits:
- Low capital and operation costs
- Excellent operational reliability
- 30% energy savings over integrated steel making; 10% savings over EAF
- Process does not require coke oven or agglomeration plant
- All chemical energy of coal is utilized and no gas is exported from the system
- Can reduce emissions by >40%; less NOx, SOx and particulate matter emitted
- Reduction, melting and slag removal occur in just 10 minutes
- Higher scrap recycling in EAF
- Reduces FeO to <2%, minimizing attack to refractories
- Allows production of high quality flat product steel in subsequent basic oxygen furnace due to dilution of tramp elements such as Cu, Pb, Sn and Cr

Block Diagram or Photo:

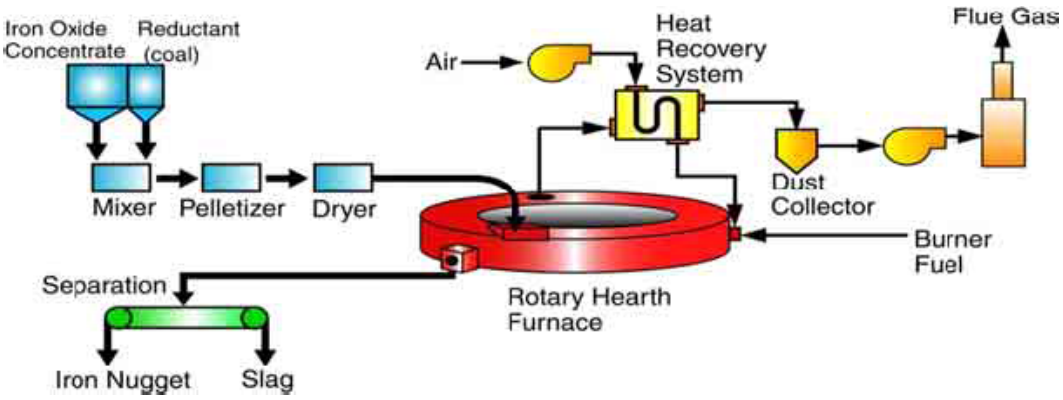


Figure 3.9: Flow sheet for the ITmk3® process illustrates the one-step furnace operation

Commercial Status: Emerging

Contact information:
Mesabi Nugget, LLC
http://mesabinugget.com

[26] Information available at: http://www.midrex.com/handler.cfm?cat_id=80

3.3.4 Paired Straight Hearth Furnace

Description:
The Paired Straight Hearth (PSH) furnace is a new coal-based reduction process for making metallized pellets for Electric Arc Furnace or Smelting processes. It operates at higher production rates and lower energy utilization than conventional rotary hearth processes. The key tall bed design, which protects the bed from reoxidization allows more complete combustion and increases productivity. Carbon is the reductant and the CO evolved in combustion is used as fuel.

Energy/Environment/Cost/Other Benefits:
- High productivity with lower energy consumpting than rotary processes
- Enables higher productivity smelting operations, when used as a pre-reducer with a smelter, to the point that the combined process is a suitable BF/coke oven replacement, using 30% less energy at lower capital cost
- Coal is used without requiring gasification

Block Diagram or Photo:

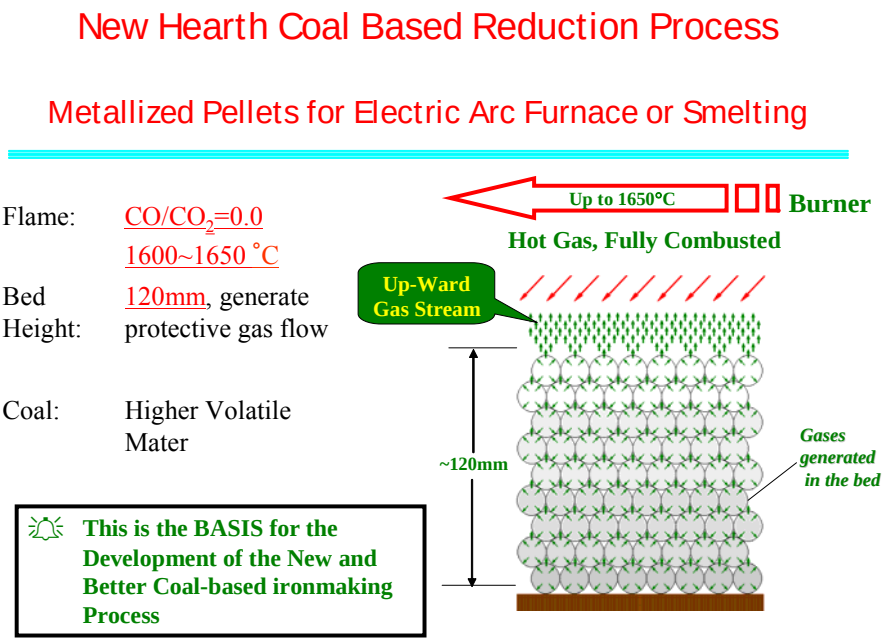


Figure 3.10: PSH process flow

Commercial Status: Emerging

Contact information:
American Iron and Steel Institute
http://www.steel.org

4 Steelmaking

4.0.1 Electrochemical Dezincing – Dezincing of Steel Scrap Improves Recycling Process[27, 28]

Description

This electrochemical dezincing process provides an environmentally friendly economic method of removing zinc from steel scrap to reuse both the steel and zinc. With the use of zinc-coated scrap increasing, steelmakers are feeling the effect of increased contaminant loads on their operations. The greatest concerns are the cost of treatment before disposal of waste dusts and the water associated with remelting zinc-coated scrap. This technology separates steel scrap into dezinced steel scrap and metallic zinc in two basic steps: 1) dissolving the zinc coating from scrap in a hot, caustic solution, and 2) recovering the zinc from the solution electrolytically. Through a galvanic process, the zinc is removed from the steel and is in solution as sodium zincate ions rather than zinc dust. The steel is then rinsed with water and ready for reuse. Impurities are removed from the zinc solution, and then a voltage is applied in order to grow metallic zinc via an oxidation-reduction reaction. All waste streams in this process are reused.

Energy/Environment/Cost/Other Benefits:

- The removal of zinc from steel scrap increases the recycleability of the underlying steel, decreases steelmaking dust, and decreases zinc in waste-water streams.
- Reduction of steelmaking dust to air and wastewater streams
- Removing zinc prior to processing of scrap saves time and money in disposal of waste dusts and water; without the zinc, this high quality scrap does not require extra handling, blending or sorting for remelting in steelmaking furnaces
- Improves the quality of steel scrap
- Produces 99.8% pure zinc for resale

Block Diagram or Photo:

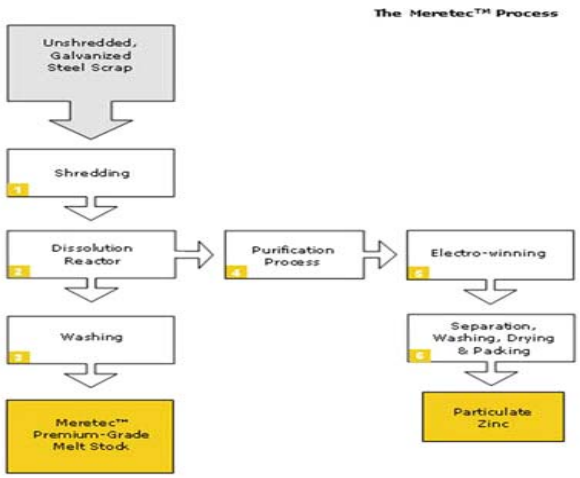


Figure 4.1: Flow diagram of Meretec Process

Commercial Status: Emerging

Contact Information:
Meretec Corporation www.meretec.com

[27] Industrial Technologies Program, Impacts, February 2006, p.60
[28] Meretec Corporation product information

4.0.2 MultiGas™ Analyzer - On-line Feedback for Efficient Combustion[29, 30]

Description:
The MultiGas™ analyzer improves continuous emissions monitoring (CEM) and on-line process tuning of combustion-dependent systems, such as boilers, turbines, and furnaces. The new multi-gas analyzer technology combines advanced Fourier transform infrared spectroscopy with advanced electronics and software. This portable compact system provides real-time measurements and on-line feedback for operational tuning of combustion-based industrial processes. It measures criteria and hazardous air pollutants that are not typically monitored on-site in real-time, such as formaldehyde and ammonia.

Energy/Environment/Cost/Other Benefits:
- Potentially lowering CEM operational energy use by 70%
- Lower operation costs - reduces maintenance and performance verification time, resulting in labor savings of up to 80%.
- Achieves higher combustion efficiency
- Reduces emissions

Block Diagram or Photo:

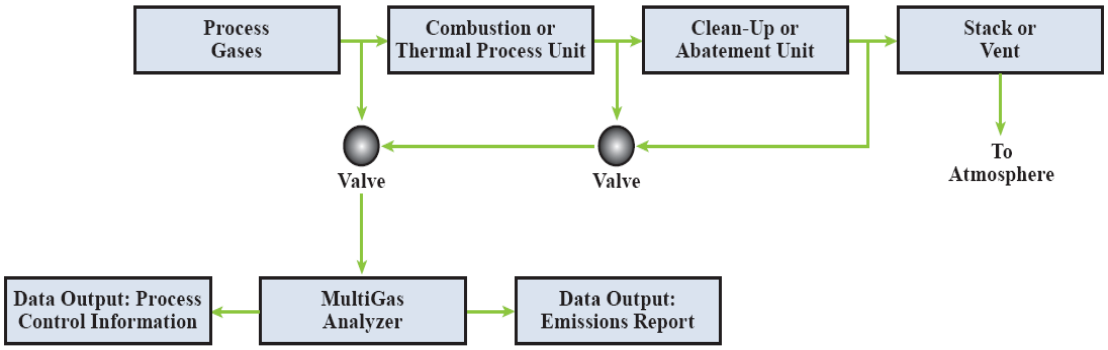


Figure 4.2: Overview of MultiGas™ analyzer system

Commercial Status: Mature

Contact Information:
MKS Instruments, Inc
http://www.mksinst.com

[29] Industrial Technologies Program, Impacts, February 2006, p.71
[30] MKS Industrial product information

4.0.3 ProVision Lance-based Camera System for Vacuum Degasser - Real-time Melt Temperature Measurement[31]

Description:
The lance-based fiber-coupled optical pyrometer measures melt temperature in a vacuum degasser, used for producing ultra-low carbon steel through ladle treatment operation. Temperature control in the ladle is crucial to downstream processes, especially in the continuous caster. To produce desired grades of steel, process models based on melt temperature and chemistry measured after tapping from the iron conversion vessel (BOF, Q-BOP or EAF) and the ladle treatment station are used to determine degassing duration, amount of additional additive (if any), and amount of oxygen blowing. The pyrometer eliminates manual or robot-operated thermocouples. It measures melt temperature automatically before and after oxygen blowing.

Energy/Environment/Cost/Other Benefits:
- Reduction in process time, enabling additional heat of steel per day and increased production value
- Reduction of energy use due to reduced processing time
- Potential emission reductions per installation per year:
  - 550 tons CO_2
  - 2.5 tons NO_2
  - 5.3 tons SO_2
  - 1.93 tons PM

Block Diagram or Photo:

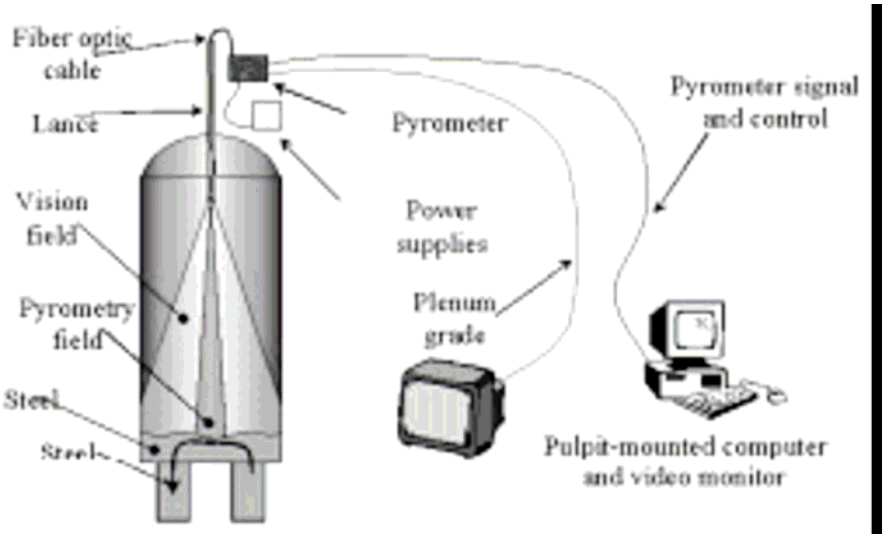


Figure 4.3: Process schematic of optical pyrometer

Commercial Status: Mature

Contact Information:
Process Metrix www.processmetrix.com

Installation information:
Granite City Works plant of United States Steel in Granite City, IL, U.S.

[31] AISI fact sheet #0034, available at http://www.steel.org.

4.1 BOF Steelmaking

4.1.1 Increase Thermal Efficiency by Using BOF Exhaust Gas as Fuel

Description:
BOF gas and sensible heat recovery (suppressed combustion) is the single most energy-saving process improvement in this process step, making the BOF process a net energy producer. By reducing the amount of air entering over the converter, the CO is not converted to CO_2. The sensible heat of the off-gas is first recovered in a waste heat boiler, generating high-pressure steam. The gas is cleaned and recovered.

Energy/Environment/Cost/Other Benefits:
- Energy savings vary between 535 and 916 MJ/ton steel, depends on the way in which the steam is recovered[32]; with increased power of 2 kWh/ton the total primary energy savings is 136%
- CO_2 reduction of 12.55 kg C per ton crude steel
- $20/ton crude steel investment costs and increased operations and maintenance costs[33, 34]
- Significant reduction of CO and PM emissions, as well as dust which can be recycled in the sinter or steel plant[7, 35]

Block Diagram or Photo:
None provided

Commercial Status: Mature

Contact Information:
None provided

[32] Stelco, 1993. Present and Future Use of Energy in the Canadian Steel Industry, Ottawa, Canada: CANMET.
[33] Inoue, K., 1995. "The Steel Industry in Japan: Progress in Continuous Casting," in *Energy Efficiency Utilizing High Technology: As Assessment of Energy Use in Industry and Buildings*, Appendix A: Case Studies, by M.D. Levine, E. Worrell, L. Price, N. Martin. London: World Energy Council.
[34] Worrell, E., J.G. de Beer, and K. Blok, 1993. "Energy Conservation in the Iron and Steel Industry," in: P.A. Pilavachi (ed.), *Energy Efficiency in Process Technology*, Amsterdam: Elsevier Applied Science.
[35] International Iron and Steel Institute. 1998. "Energy Use in the Steel Industry." September. Brussels, Belgium: International Iron and Steel Institute.

4.1.2 Use Enclosures for BOF

Description:
BOF enclosures operate by covering mixer shop filling, mixer pouring, de-slagging station, converter charging, converter tapping and bulk material handling system on BOF top platform. On the charging top side, a dog house enclosure captures secondary fumes generated during charging. Rectangular high pick-up velocity suction hoods above charging side are connected to duct lines below the operating platform. Suction hoods capture dust during tapping operations above the receiving ladle. Deflector plates guide fumes towards suction hoods. Below the operating platform is a header duct that connects to a centralized fume extraction system of electrostatic precipitators, fans and a stack. Capacity varies between 1,000,000 m^3/h to 2,600,000 m^3/h, depending on heat capacity and operating sequence. Space can sometimes be a limited factor for this technology.

Energy/Environment/Cost/Other Benefits:
- Better working conditions in terms of temperature and dust control
- Visibility of steel making operation and safety improves
- Accumulation of dust over building roofs can be avoided
- Collected dust can be recycled in steel plant

Block Diagram or Photo:

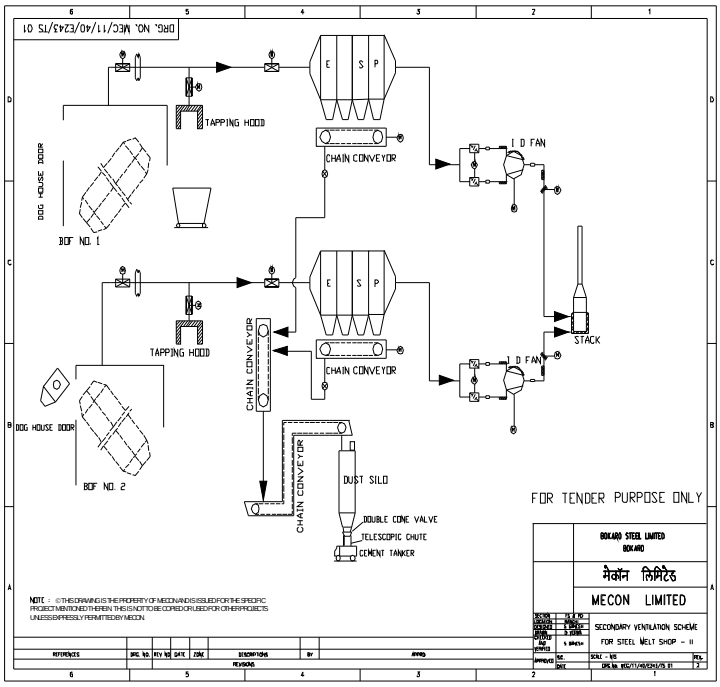


Figure 4.4: Sketch with two converters enclosed

Commercial Status: Mature

Contact Information:
Consultant: MECON Ltd., Ranchi, India
ranchi@mecon.co.in

Suppliers:
SMS Demag-Delhi
VAI-Siemens Alstom Project, Kolkata, India,

Installation Information:
TISCO

4.1.3 Control and Automization of Converter Operation

Description:
As converters have become larger, operational control and automatic operation have been promoted with various advantages, which are discussed below. Along with the advancement of processing computers and peripheral measuring technology, blowing control for converters has shifted from a static control system to a dynamic or fully automatic operational control system. Indirect measurement of the exhausted gas method is employed in Europe and the United States, whereas direct measurement by the sublance method – direct measurement of the temperature of molten steel simultaneously during blowing – is employed in Japan. Sublance is used for bath leveling, slag leveling, measurement of oxygen concentration and slag sampling.

Energy/Environment/Cost/Other Benefits:
- Increase productivity and product quality
- Decreased labor
- Improved working environment

Block Diagram or Photo:

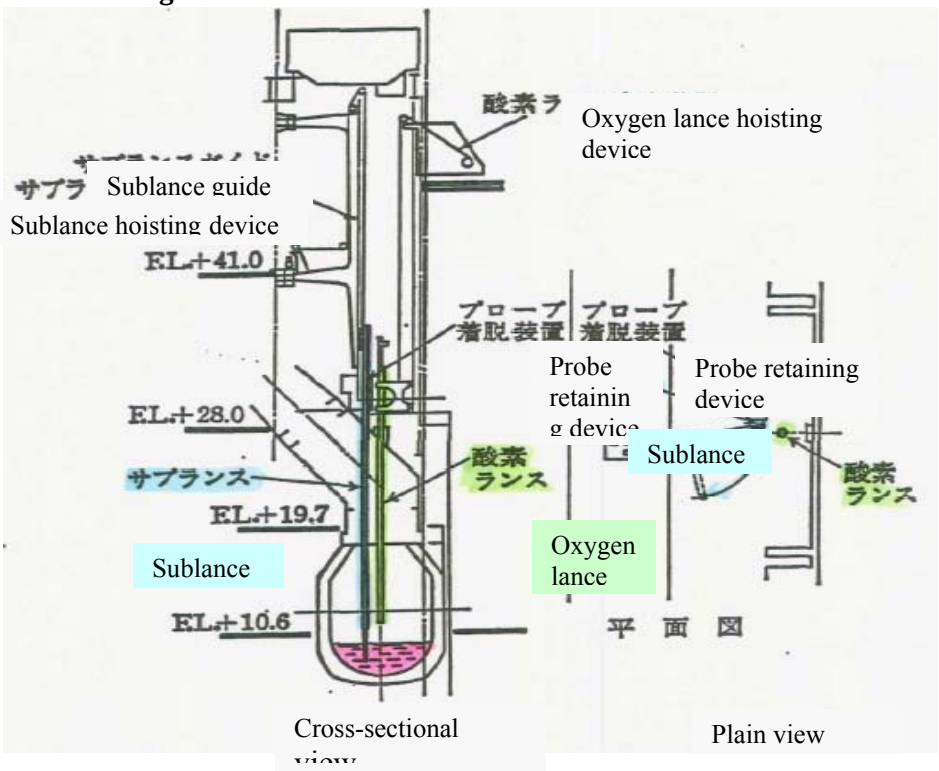


Figure 4.4: Overview of sublance equipment

Commercial Status: Mature

Contact Information:
Nisshin Steel Co., Ltd.
http://www.nisshin-steel.co.jp/nisshin-steel/english/index.htm

4.1.4 Exhaust Gas Cooling System (Combustion System)

Description:
Since steel refining is conducted in a short period of time, about 35 minutes per charge, the dust concentration is very high, usually about 15-25g/m^3N at the inlet of the stabilizer, although in the case of the combustion-type converters, it depends on the amount of combustion air. Dust after the pre-treatment at the stabilizer or first dedusting device is fine grain with a median diameter of 0.2μm, mainly consisting of iron oxide ore. Ingredients of exhaust gas vary along with the process of the converter operation. Combustion-type converters oxidize CO into CO_2 through combustion, in order to prevent an explosion in the smoke duct or treatment equipment. For the purpose of stabilizing such variation, pre-treatment of hot metal is conducted before hot metal is charged into the converter. Exhaust gas treatment consists of an exhaust gas cooling system and a cleaning system. The general combustion-type system is provided with sufficient space between the converter throat and the hood. The second blower sufficiently sends the amount of air that is necessary for CO gas combustion. CO gas is combusted at the hood and the smoke duct into high-temperature gas (1,600°C). The exhaust heat boiler recovers the latent heat and sensible heat of gas as steam through heat exchange.

There are two types of steam recovery boilers, a full boiler equipped with a super heater and coal economizer, and a half boiler without such equipment. The temperature of gas at the boiler outlet is 300°C for full boilers, and about 1,000°C for half boilers. Dust must be removed prior to atmospheric discharge. There are several types of dust removal machines, such as electrical precipitators, venturi scrubbers and bag filters. Among them, electrical precipitators are the most popular. There are both wet-type and dry-type electrical precipitators. The dry type is more popular because the wet type has problems with sludge treatment and erosion control.

Energy/Environment/Cost/Other Benefits:
- Dust removal

Block Diagram or Photo:

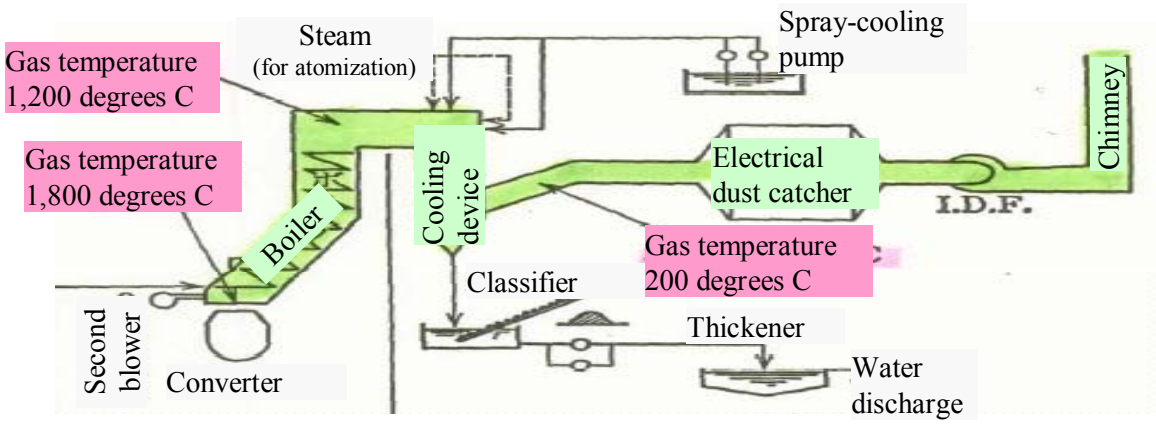


Figure 4.5: Overview of combustion-type system

Commercial Status: Mature

Contact Information:
Nisshin Steel Co., Ltd.
http://www.nisshin-steel.co.jp/nisshin-steel/english/index.htm

4.1.5 OG-boiler System (Non-combustion)/Dry-type Cyclone Dust Catcher

Description:
Since steel refining is conducted in a short period of time, about 35 minutes per charge, the dust concentration is very high. In non-combustion-type converters with a gas recovery function, the dust concentration is 70-80g/m^3N at the inlet of the first dedusting device. Non-combustion-type converters, without combusting CO gas, manage the volume of intake air from the throat, and control the concentration to below the explosion limit, thereby recovering CO as fuel. Exhaust gas treatment consists of an exhaust gas cooling system and a cleaning system.

Non-combustion-type systems can be largely divided into the OG-type and the IC (IRSID-CAFL) type. The OG-type system basically has no space between the throat and the hood skirt, and controls pressure at the closed throat. The IC-type system has a gap of several hundred millimeters between the throat and the hood skirt (which has a slightly larger diameter than that of the throat), and controls pressure at the throat opening. The non-combustion-type system keeps gas temperature low and shuts out combustion air; therefore, the cooling device and dedusting device installed in the system are smaller than those installed in the combustion-type system. Since the system handles gas that mainly consists of CO, attention is paid to sealing for the flux and coolant input hole and the lance hole, and leak control at the periphery of devices, as well as purge at the gas retention part. As the volume of converters increases, exhaust gas treatment equipment becomes larger. Large converters adopt the non-combustion-type system for various reasons, such as the relatively small size of the system as a whole, ease of maintenance, and stable dedusting efficiency. The OG-type system is frequently used because of its operational stability. The OG-type cooling system makes it possible not only to recover the sensible heat of exhaust gas as steam, but also to increase the IDF efficiency by lowering the temperature of the exhaust gas by use of a cooling device.

Energy/Environment/Cost/Other Benefits:
- OG-boiler system recovers 65% of the sensible heat of the total exhaust gas, about 70 kg/t
- Increases the IDF efficiency by lowering the temperature of the exhaust gas, achieving high-speed oxygen feedi

Block Diagram or Photo:

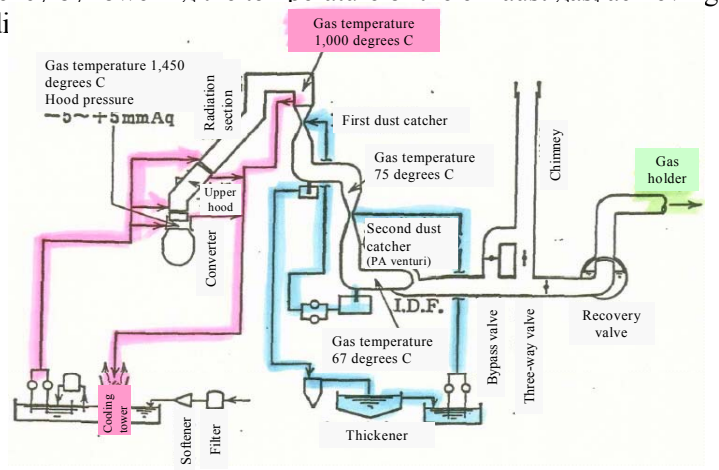


Figure 4.6: Non-combustion OG-type process

Commercial Status: Mature

Contact Information:
Nisshin Steel Co., Ltd. http://www.nisshin-steel.co.jp/nisshin-steel/english/index.htm

4.1.6 Laser Contouring System to Extend the Lifetime of BOF Refractory Lining[36, 37]

Description:
The Laser Contouring System (LCS) allows rapid measurements of vessel wall and bottom-lining thickness in the steel furnace or ladle environments. The LCS measures refractory lining thickness and incorporates high-speed laser-based distance measuring equipment with a robust mechanical platform and easy-to-use software. With a laser scan rate of over 8,000 points per second, a single vessel scan can include over 500,000 individual contour measurements, providing detailed contour resolution and accurate bath height determination. LCS is available as a mobile platform or a fixed position installation. The LCS maps the entire vessel interior in less than 10 minutes and provides detailed contour resolution and vessel lining thickness with over 500,000 individual contour measurements

Energy/Environment/Cost/Other Benefits:
- Reduce energy usage via rapid real-time measurement and no loss of process time
- Reduction of maintenance on BOF refractory via automated furnace inspection

Block Diagram or Photo:

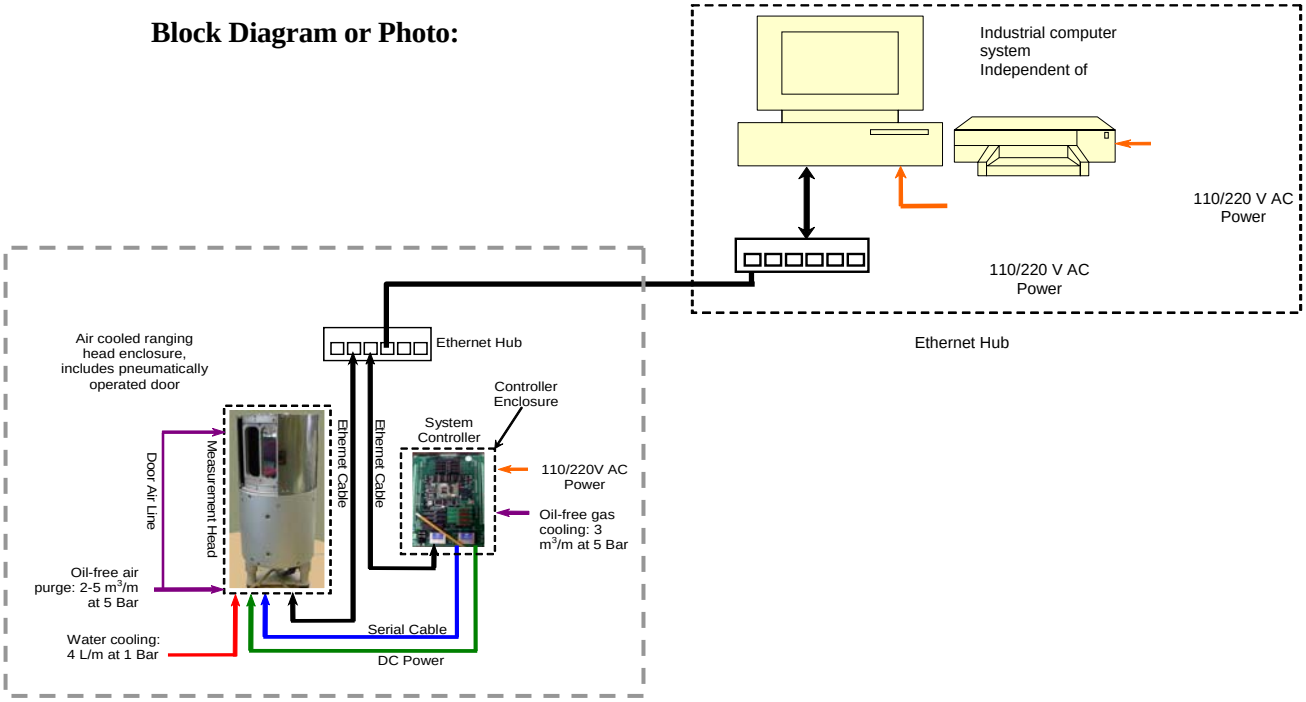


Figure 4.7: LCS layout

Commercial Status: Mature

Contact Information:
Process Metrix
www.processmetrix.com

Installation information:
Nucor Steel Corp. plant in Berkeley, SC, U.S.

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[36] Industrial Technologies Program, Impacts, February 2006, p.61
[37] Process Metrix product information

4.2 EAF Steelmaking

4.2.1 Elimination of Radiation Sources in EAF Charge Scrap

Description:
Effective radiation control involves a redundant scan process to inspect incoming scrap material for hidden radiation sources.
Purchased scrap may undergo radiation detection by the supplier prior to delivery onsite. All incoming scrap to the facility is passed through the Exploranium AT-900 detection equipment. Scrap flagged as high risk undergoes additional scanning from hand detectors. A second scan with the AT-900 is performed prior to melt shop delivery and a final scan is performed on each magnet load as charge buckets are filled. EAF baghouse detectors define when, if any, radioactive material has been melted.

Energy/Environment/Cost/Other Benefits: Reduced radiation

Block diagram or photo:

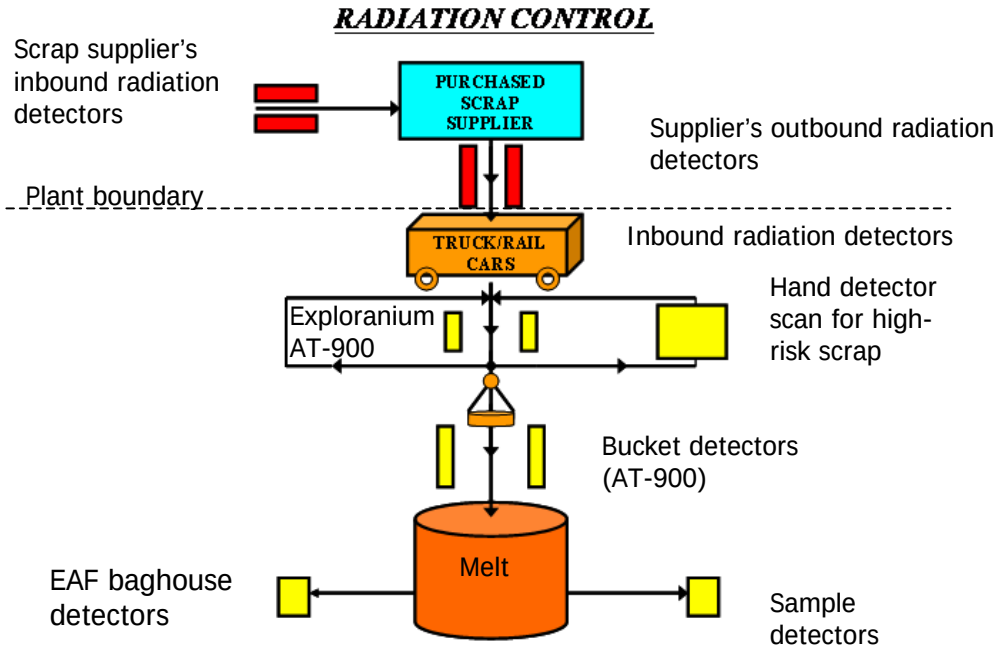


Figure 4.8: Schematic of radiation control process[38]

Commercial Status: Mature

Contact Information:
The Timken Company
www.timken.com

[38] Source: the Timken Company

4.2.2 Improved Process Control (Neural Networks)

Description:
Improved process control (neural networks) can help to reduce electricity consumption beyond that achieved through classical control systems. For example, neural networks or "fuzzy logic" systems analyze data and emulate the best controller. For EAFs, the first "fuzzy logic" control systems have been developed using current power factor and power use to control the electrodes in the bath[39].

Energy/Environment/Cost/Other Benefits[40]:
- Electricity savings of 30 kWh/t steel
- Increase in productivity of 9 to 12%[14]
- Reduced electrode consumption of 25%[14]
- Capital and commissioning costs are about $250,000 per furnace, or about $0.95/t in the U.S.[41]
- Furnace maintenance costs are reduced as well; annual operating costs savings of $1/t steel

Block Diagram or Photo:
None provided

Commercial Status: Mature

Contact Information:
None provided

Installation information:
Ternium Hylsa plant in Monterrey, Mexico.

[39] Staib, W.E. and N.G. Bliss, 1995. "Neural Network Control System for Electric Arc Furnaces" Metallurgical Plant & Technology International 2: 58-61.
[40] The actual savings depend on the scrap used and the furnace operation
[41] Kimmerling, K., 1997. Personal communication and reference list, Neural Applications Corporation, Coralville, IA (26 August 1997).

4.2.3 Oxy-fuel Burners/Lancing

Description:

Oxy-fuel burners/lancing can be installed in EAFs to reduce electricity consumption by substituting electricity with oxygen and hydrocarbon fuels. They reduce total energy consumption because of:

- Reduced heat times, which save 2-/3 kwh/ton/min of holding time
- Increased heat transfer during the refining period
- Facilitates slag foaming, which increases efficiency of oxygen usage and injected carbon

Care must be taken to use oxy-fuel burners correctly, otherwise there is the risk is that total energy consumption and greenhouse gases will increase.

Energy/Environment/Cost/Other Benefits:

- Electricity savings of 0.14 GJ/tonne crude steel, typical savings range from 2.5 to 4.4 kWh per Nm^3 oxygen injection[42, 43, 44, 45] with common injection rates of 18 Nm^3/t
- Natural gas injection is 10 scf/kWh ($0.3m^3$/kWh)[46] with typical savings of 20 to 40 kWh/t[47]
- Retrofit Capital Costs of $4.80/t crude steel on an EAF of 110 tons
- Improved heat distribution leads to reduced tap-to-tap times of about 6%[48], leading to estimated annual cost savings of $4.0/t[49]
- Reduction of nitrogen content of the steel, leading to improved product quality[50]

Block Diagram or Photo:



Figure 4.9: Oxy-fuel burner

Commercial Status: Mature, widely used

Contact Information:

American Combustion International	Process Technology	Air Products and Chemicals, Inc.
www.americancombustion.com	www.pticombustion.com	www.airproducts.com

[42] International Iron and Steel Institute, Committee on Technology, 1982. *Energy and the Steel Industry*, Brussels, Belgium: IISI.
[43] Center for Materials Production, 1987. *Technoeconomic Assessment of Electric Steelmaking Through the Year 2000*, EPRI/CMP, Report 2787-2, October 1987.
[44] Haissig, M., 1994. "Enhancement of EAF Performance by Injection Technology" *Steel Times*, October 1994 pp.391-393.
[45] Stockmeyer, R., K-H. Heinen, H. Veuhoff, and H. Siegert, 1990. "Einsparung von elektrischer Energie am Lichtbogenofen durch eine neue Ausqualmregelung" *Stahl u. Eisen* **110**(12): 113-116.
[46] Center for Materials Production, 1992. *Electric Arc Furnace Efficiency*, EPRI/CMP, Report 92-10, Pittsburgh, PA: CMP.
[47] Jones, J. A. T. 1996. "New Steel Melting Technologies: Part III, Application of Oxygen Lancing in the EAF." *Iron and Steelmaker* 23 (6): 41-42.
[48] Center for Materials Production, 1995. *Coal & Oxygen Injection in Electric Arc Furnaces*, Tech Bulletin CMP 95-7TB, CMP, Pittsburgh, PA.
[49] Center for Materials Production, 1987. *Technoeconomic Assessment of Electric Steelmaking Through the Year 2000*, EPRI/CMP, Report 2787-2, October 1987.
[50] Douglas, J., 1993. "New technologies for Electric Steelmaking" *EPRI Journal*, October/ November 1993, pp.7-15.

4.2.4 Scrap Preheating

Description:
Scrap preheating is a technology that can reduce the power consumption of EAFs through from using the waste heat of the furnace to preheat the scrap charge. Old (bucket) preheating systems had various problems, e.g., emissions, high handling costs, and a relatively low heat recovery rate. Modern systems have reduced these problems and are highly efficient. The energy savings depend on the preheat temperature of the scrap. Various systems have been developed and are in use at various sites in the U.S. and Europe, i.e., Consteel tunnel-type preheater, Fuchs Finger Shaft, and Fuchs Twin Shaft. All systems can be applied to new constructions, and also to retrofit existing plants.

4.2.4.A. Tunnel Furnace - CONSTEEL Process

Description:
The Consteel process consists of a conveyor belt with the scrap going through a tunnel, down to the EAF through a "hot heel". Various U.S. plants have installed a Consteel process, as well as one plant in Japan.

Energy/Environment/Cost/Other Benefits Consteel process:
- Productivity increase of 33%[51]
- Reduced electrode consumption of 40%[29]
- Reduced dust emissions[52]
- Electricity savings estimated to be 60 kWh/t for retrofits
- Annual operating cost savings of $1.90/t crude steel (including productivity increase, reduced electrode consumption, and increased yield
- Retrofit Capital Costs $4.4 to $5.5/t ($2M for a capacity of 400,000 to 500,000 t/year[53])

Block Diagram or Photo:

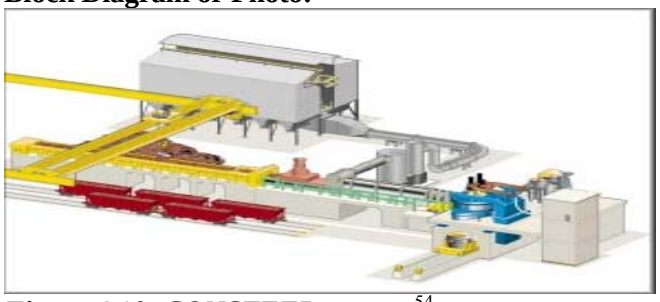


Figure 4.10: CONSTEEL process[54]

Commercial Status: Mature

Contact Information:
Techint Technologies, www.techint-technologies.com

Installation information:
Wheeling Pittsburgh Steel plant in Mingo Junction, WV, U.S.

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[51] Jones, J. A. T. 1997a. "New Steel Melting Technologies: Part X, New EAF Melting Processes." *Iron and Steelmaker* **24**(January)**:** 45-46.
[52] Herin, H.H. and T. Busbee, 1996. "The Consteel® Process in Operation at Florida Steel*" Iron & Steelmaker* **23**(2): 43-46.
[53] Bosley, J. and D. Klesser, 1991. *The Consteel Scrap Preheating Process*, CMP Report 91-9, Center for Materials Production, Pittsburgh, PA.
[54] Source: http://www.corefurnace.com/meltshop_01.html

4.2.4.B. Post Consumption Shaft Furnace (FUCHS)

Description:

The FUCHS shaft furnace consists of a vertical shaft that channels the offgases to preheat the scrap. The scrap can be fed continuously or through a so-called system of 'fingers'[55]. The optimal recovery system is the 'double shaft' furnace, which can only be applied for new construction. The Fuchs-systems make almost 100% scrap preheating possible, leading to potential energy savings of 100-120 kWh/t[56]. Carbon monoxide and oxygen concentrations should be well controlled to reduce the danger of explosions, as happened at one plant in the U.S.

Energy[57]/Environment/Cost/Other Benefits FUCHS process:

- Electricity savings of 120 kWh/t and fuel increases of 0.7 GJ/t
- Annual operating cost savings of $4.5/t (excluding saved electricity costs)
- Retrofit Capital Costs of about $6/t crude steel[33] for and existing 100 t furnace
- Reduced electrode consumption
- Yield improvement of 0.25-2%[33, 58]
- Up to 20% productivity increase[33]
- 25% reduced flue gas dust emissions (reducing hazardous waste handling costs)[36]

Block Diagram or Photo:

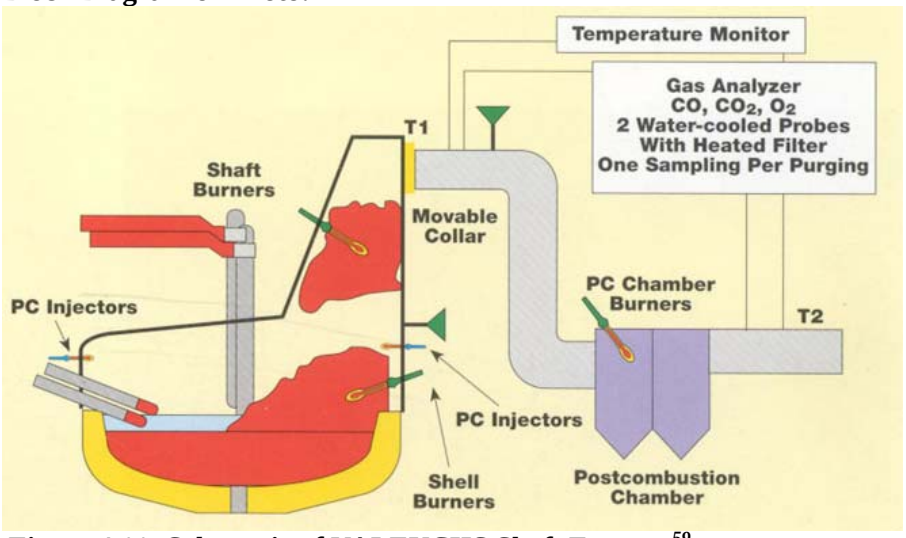


Figure 4.11: Schematic of VAI FUCHS Shaft Furnace[59]

Commercial Status: Mature

Contact Information:

Siemens VAI, www.vai.at/view.php3?f_id=3057&LNG=EN&flash=show

Installation information:

Arbed plant in Aristrain, Spain.

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[55] VAI, 1997. *FUCHS Shaft Furnaces, The Power, The Performance, The Profit*, Linz, Austria: Voest Alpine Industrieanlagenbau Gmbh.

[56] Hofer, L., 1997. Personal communication, Voest Alpine Industrieanlagenbau Gmbh, Linz, Austria, 25 September 1997.

[57] The energy savings depend on the scrap used, and the degree of post-combustion (oxygen levels)

[58] Center for Materials Production. 1997. *Electric Arc Furnace Scrap Preheating.* Tech Commentary, Pittsburgh, PA: Carnegie Mellon Research Institute.

[59] Source: http://www.vai.at/view.php3?f_id=1029&LNG=EN

4.2.5 Contiarc

Description:
Mannesmann Demag, Germany, is developing the Contiarc process. It consists of a continuous scrap smelting process (instead of the current batch process) with a capacity of 1 Mt/year. The design aims to be energy efficient and produce low emission[60,61].

Energy/Environment/Cost/Other Benefits:
- Electricity use is 250-258 kWh/t with fuel injection of 0.48 GJ/t[38, 62]
- The production costs are expected to be $9-13 lower per ton steel produced or up to a 20% reduction[38, 40]

Block Diagram or Photo:

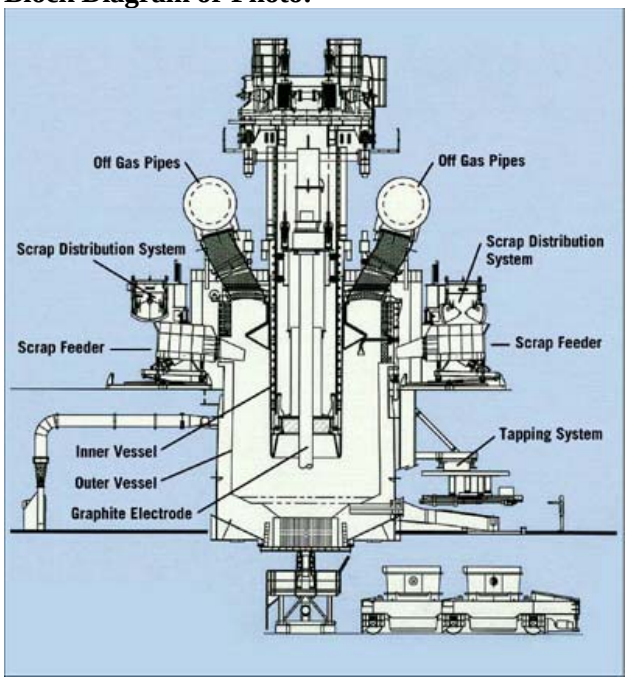


Figure 4.12: Layout of ACIPCO's Contiarc furnace[63]

Commercial Status: Emerging

Contact Information:
American Cast Iron Pipe Company
www.acipco.com
Alabama Power
www.southernco.com/alpower

Mannesmann Demag
www.mannesman-demag.com

[60] Reichelt, W. and W. Hofmann, 1996. "'Contiarc' - An Energy Optimised and Environmental Scrap Melting Process." In *Stahl und Eisen* 116 (5): 89-92 (in German).
[61] Möllers, G., W. Reichelt, H. Vorwerk. 1997. "New Technologies For Electric Steelmaking." In *12th Aachener Stahl-Kolloquim, Proceedings*. Aachen, Germany.
[62] Mannesmann Demag. 1998. "Contiarc, The Revolutionary Electric Arc Melting Furnace." *Brochure*. Pittsburgh, PA: Mannesmann Demag Corporation
[63] Source: http://www.moderncasting.com/archive/Features/2002/feature_069_03.asp

4.2.6 VIPER Temperature Monitoring System

Description:
VIPER sensor is a non-contact instrument designed to accurately measure steel melt temperature in real-time. It was adapted to monitor radiant emissions through the virtual pipe of a specially designed CoJet burner. VIPER has the potential to reduce processing time, optimize energy consumption, reduce consumables use, and improve safety in EAF applications

Energy/Environment/Cost/Other Benefits[64]:
- Improved safety; reduced or eliminated manual thermocouple measurements and highly accurate, continuous temperature monitoring
- Reduced energy consumption
- Reduced processing time
- Depending on burner flow rate, measurement duration and gas used, VIPER measurements can be less expensive than immersion thermocouples
- Savings in operations through reduced labor requirements

Block Diagram or Photo:

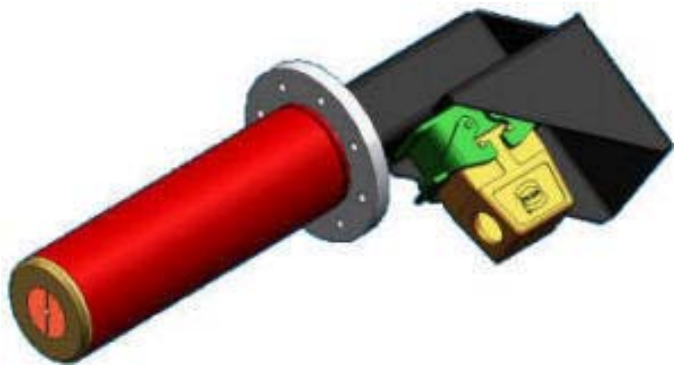


Figure 4.13: VIPER sensor

Commercial Status: Mature

Contact Information:
Process Metrix
www.processmetrix.com
+1-925-460-0385
phues@processmetrix.com

[64] http://www.processmetrix.com/viper.htm

5 Ladle Refining and Casting

5.1 Ladle Refining for BOF and EAF

No technologies available at the time of publication. Technologies will be added in the future as appropriate.

5.2 Casting

5.2.1 Castrip® Technology

Description
The Castrip® process has been developed to allow the direct casting of thin strip from liquid steel, in gauges currently ranging from 0.8mm to 2.0 mm.

Energy/Environment/Cost/Other Benefits:

- Potential energy savings of 80 to 90% over conventional slap casting and hot rolling methods
- More tolerant of high residual elements without loss of quality, enabling greater flexibility in ferrous feed sourcing
- Higher scrap recycling rates potential and less dependence on pig iron and HBI

Block Diagram or Photo:

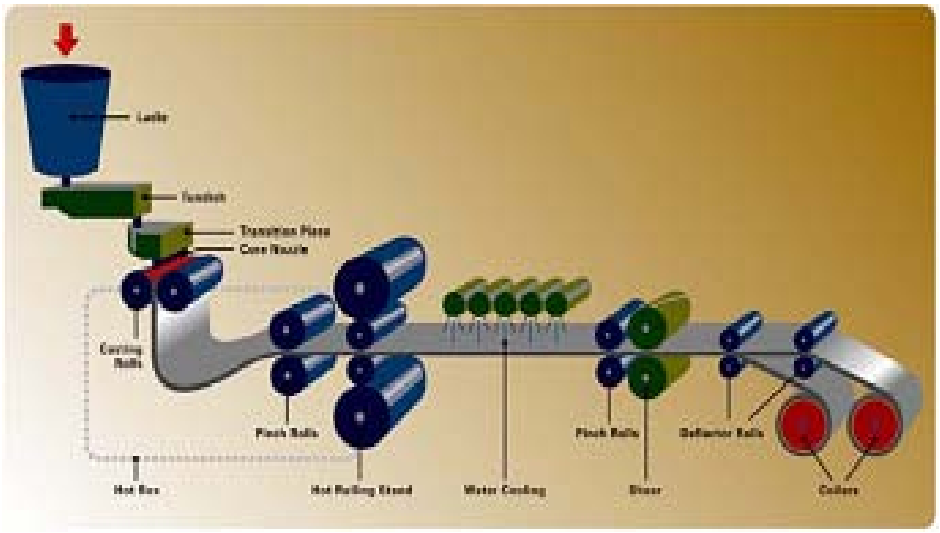


Figure 5.1: Castrip® Process flow diagram

Commercial Status: Emerging

Contact Information:
Castrip LLC
http://www.castrip.com

6 Rolling and Finishing

No technologies available at the time of publication. Technologies will be added in the future as appropriate.

7 Recycling and Waste Reduction Technologies

7.1 Reducing Fresh Water Use

Description:
To reduce steel works dependence on fresh water, the following efforts have been made at Port Kembla Steelworks, Australia:

- Municipal waste-water reclamation – The treatment of sewerage water using micro-filtration and reverse osmosis technology for re-use as industrial water, up to 20 ML/day
- Internal waste-water recycling schemes – Cooling tower blowdown water from the hot strip mill and slab casters does not go to the drain, but is treated and reused for dust collection in steelmaking
- Stormwater containment initiatives – 13ML synthetic lined water recovery basin in coke ovens area collects rainwater, coal stockpile run-off water, and spent water from coke quenching for re-use at gas processing and coke quenching

Energy/Environment/Cost/Other Benefits:

- Using recycled sewerage water has reduced fresh dam water use on site by 20ML/day
- Hot strip mill and slab caster blowdown water saves steelmaking 0.5ML/day
- Recycling reduces fresh dam water use from 2.3kL/slab tonne to 1.0kL/slab tonne

Block Diagram or Photo:

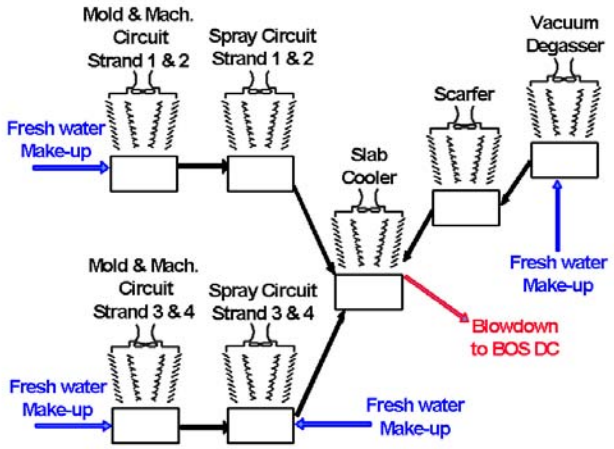


Figure 7.1: Water flow between the slab caster cooling towers

Commercial Status: Mature

Contact information:

Sydney Water
http:///www.sydneywater.com.au

BlueScope Steel
http://www.bluescopesteel.com

7.2 Slag Recycling

Description:
Slag is a by-product of iron and steelmaking, not a waste. Slag pulverization is a process during which water is sprayed when the slag temperature is at 600-800°C. The water spray produces hot steam, which reacts with free calcium oxide and magnesium oxide. Consequently, the slag is pulverized due to the volume expansion, thus making the iron and steel separate naturally from the slag. Slag is also used outside of steel making, e.g., in water/bottom muck purification materials to reduce phosphate concentration in red tides and as marine block to help grow seaweed.

Energy/Environment/Cost/Other Benefits:
- Around 3.8 million t/year of scrap steel is recovered from slag produced
- Revenue generated is equivalent to 3.8 billion Yuan/year, based on 1,000 Yuan ($130 2006 US)/t scrap steel
- Substitute for cement in building industry, thereby minimizing CO_2 emissions generated by cement production
- Land area occupied by piled slag minimized by slag reutilization
- Application of slag in Japan (marine block and water/bottom much purification materials)
  - Reduce phosphate concentration that causes red tide
  - Fix hydrogen sulfide (cause of blue tide)
  - Grow seaweed to restore lost shallows in seaweed beds
- Other applications include concrete aggregate, railroad ballast, agricultural use, sewage trickling filters, and construction[65]

Block Diagram or Photo:

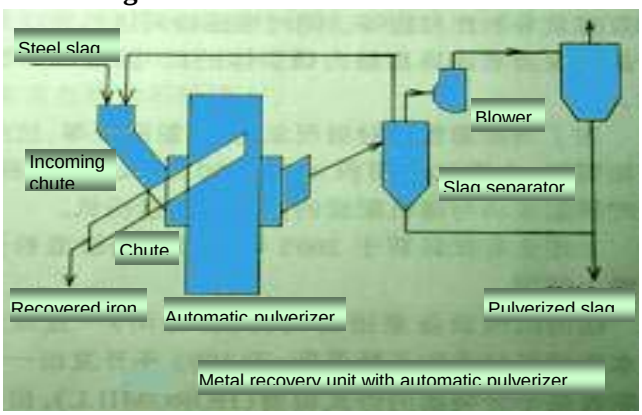


Figure 7.2: Slag pulverization process

Commercial Status: Emerging

Contact information:
Central Engineering Institute of Building Industry, Beitai Steel and Hunan Lianyuan Steel
JFE Steel Corporation
http://www.jfe-steel.co.jp
Japan Iron and Steel Federation
http://www/jisf.or.jp

[65] Baker Environmental, Inc. 1992. *Report on Steel Industry Waster Generation, Disposal Practices, and Potential Environmental Impact.* American Iron and Steel Institute.

7.3 Rotary Hearth Furnace Dust Recycling System

Description:
Dust recycling in the rotary hearth furnace (RHF) was applied at Nippon Steel's Kimitsu Works in 2000. The dust and sludge, along with iron oxide and carbon, are agglomerated into shaped articles and the iron oxide is reduced at high temperatures. Zinc and other impurities in the dust and sludge are expelled and exhausted into off-gas[66].

Energy/Environment/Cost/Other Benefits:
- DRI pellets made from the dust and sludge have 70% metallization and are strong enough to be recycled to the blast furnaces[2]
- Waste reduction and decreased disposal costs
- Extended landfill life
- Recovery of unused resources (recycling iron, nickel, zinc, carbon, etc.)
- Increase in productivity: 1kg of DRI charged per ton of BF smelt pig iron
- Decrease in fuel ratio to BF to 0.2kg/t-pig
- Decrease in coke ratio by charging DRI to BF

Block Diagram or Photo:

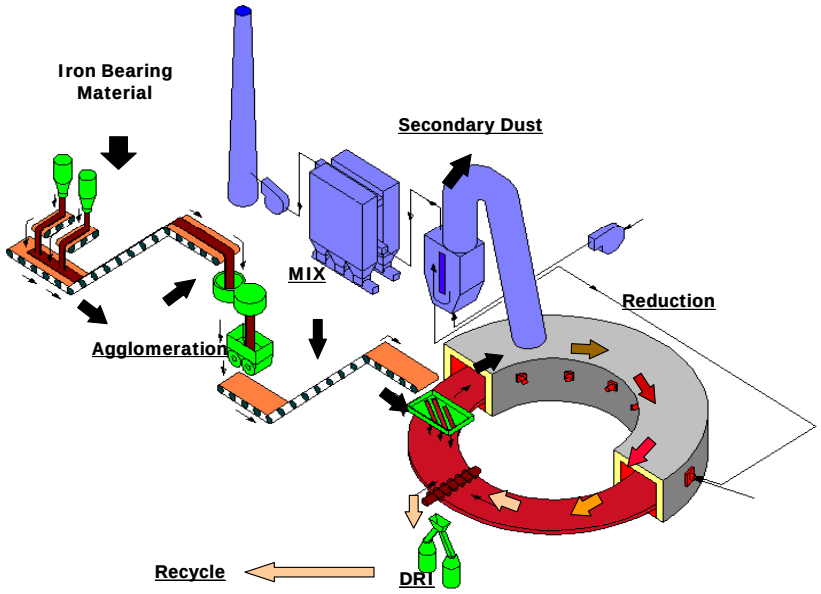


Figure 7.3: General process flow of RHF

Commercial Status: Emerging

Contact information:
Shinjiro Uchida, Nippon Steel Engineering
http://www.nsc-eng.co.jp

66 Information available at: http://www0.nsc.co.jp/shinnihon_english/kenkyusho/contenthtml/n94/n9424.pdf

7.4 Activated Carbon Absorption

Description:
Use of activated carbon to remove high pollutant concentrations has been proven successful in many cases. In cokemaking, activated carbon absorption system is used not only to eliminate the yellow brown color typical of coke wastewater (which may cause complaints from stakeholders) but also to reduce the COD of the secondary wastewater treatment plant.

Energy/Environment/Cost/Other Benefits:
- Eliminate the yellow brown color of coke wastewater
- Significant reduction of COD of the secondary wastewater treatment plant to below 5 mg/ℓ
- Heavy metals removal

Block Diagram or Photo:



Figure 7.4: Activated Carbon Equipment

Commercial Status: Mature

Contact information:
Mr. Youngdo Jang
Department of Environment & Energy, POSCO
T +82-54-220-5773
ydjang@posco.co.kr

Installation information:
First commercial facility in Kwangyang; secondary wastewater treatment plant operated since 1988 and installation of coke wastewater plant was done in 2002.

8 Common Systems

8.1 Auditing Rotary Machines for Pump Efficiency

Description:
ESCO-PRO (POSCO venture company) developed auditing methodology for pump efficiency to measure temperature and pressure of fluid. From the inlet and outlet temperature and pressure measurement, the pump efficiency is calculated.

Energy/Environment/Cost/Other Benefits:
- Energy saving between 22-34%
- $63,000-$65,000/year reduction in power consumption

Block Diagram or Photo:

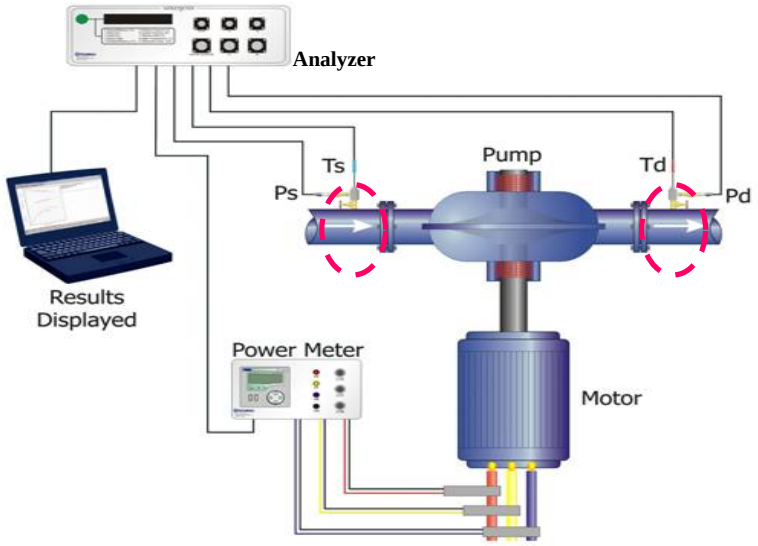


Figure 8.1: Flow diagram of auditing rotary machines system

Commercial Status: Mature

Contact information:
Yun Sik Jung, Environmental & Energy Dept., POSCO
http://www.posco.co.kr

8.2 AIRMaster+ Software Tool – Improved Compressed Air System Performance

Description:
The AIRMaster+ software tool models the supply-side of a compressed air system to identify efficiency improvement opportunities. Using plant-specific data, the free software tool evaluates the operational costs for various compressed air equipment configurations and system profiles. The software provides estimates of potential savings gained from selected energy efficiency measures and calculates the associated simple payback periods.

The AIRMaster+ software includes a database of industry-standard compressors and creates an inventory specific to the actual air compressors onsite based on user input. The software simulates existing and modified compressed air system operations. It can model part-load system functions for an unlimited number of rotary screws, reciprocating and centrifugal air compressors operating simultaneously with independent control strategies and schedules.

Energy/Environment/Cost/Other Benefits:
- Develops a 24-hour metered airflow or power data load profile for each compressor
- Calculates life-cycle costs
- Inputs seasonal electrical energy and demand charges
- Tracks maintenance histories for systems and components
- Evaluates energy savings potentials of the following energy efficiency actions: reducing air leaks, improving end-use efficiency, reducing system air pressure, using unloading controls, adjusting cascading set points, using an automatic sequencer, reducing run-time, and adding a primary receiver volume

Block Diagram or Photo:



Figure 8.2: Screen Shot of AIRMaster+

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.3 Combined Heat and Power Tool – Improved Overall Plant Efficiency and Fuel Use

Description:
The Combined Heat and Power (CHP) tool identifies opportunities for the application of CHP systems to re-use waster heat and determines optimal equipment size, implementation costs, and the payback for investing in CHP technologies.

The tool can be used to size or select design parameters for a new CHP system or to optimize a system in use. Site-specific data can be entered into the tool or default settings from the tool's database can be used to generate:

- Current energy use and performance data for selected furnaces/boilers and turbines
- Energy use data for a CHP system
- Estimated energy savings
- Cost details for implementing a CHP system
- Payback period based on cost data provided for the fuel, electricity, and equipment used in a CHP system

Energy/Environment/Cost/Other Benefits:

- Evaluates the feasibility of using gas turbines to generate power and using turbine exhaust gases to supply heat to industrial heating systems
- Provides analysis for the following three commonly used systems:
  - Fluid Heating in Fired Heat Exchangers
  - Exhaust Gas Heat Recover in Heaters
  - Duct Burner Systems

Block Diagram or Photo:

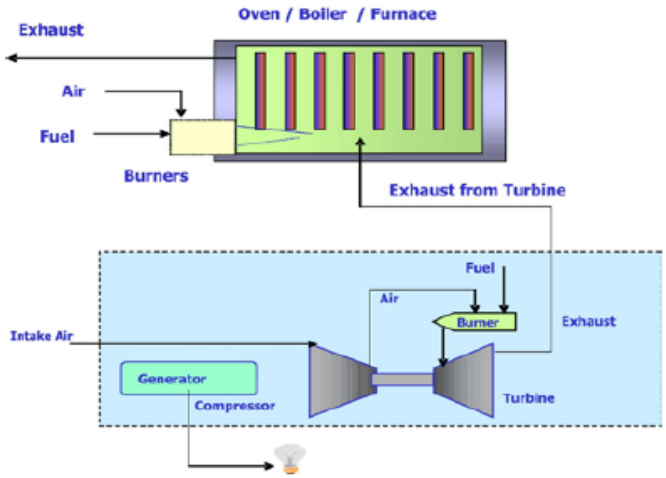


Figure 8.3: Example of CHP application – exhaust gases from a turbine is used to heat fluids in a heat exchanger

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.4 Fan System Assessment Tool – Efficiency Enhancement for Industrial Fan Systems

Description:
The Fan System Assessment Tool (FSAT) quantifies energy consumption and energy savings opportunities in industrial fan systems, helping users understand how well their fan systems are operating and determine the economic benefit of system modifications.

FSAT allows users to input information about their fans and motors and calculates the energy used by the fan system and the overall system efficiency. It approximates potential energy and cost savings, and helps determine which options are most economically viable when multiple opportunities exist.

Energy/Environment/Cost/Other Benefits:
- Capabilities include:
  - Determining fan system efficiency
  - Identifying degraded fans
  - Collecting data for trending system operation
  - Quantifying potential costs and energy savings for various operating configurations
- Help users calculate the differences between rated and installed performance due to issues such as:
  - High duct velocity
  - Discharge dampers locked in position
  - Obstructed inlets
  - Incorrectly sized fans
  - Poor duct geometry
  - Degraded impellers

Block Diagram or Photo:

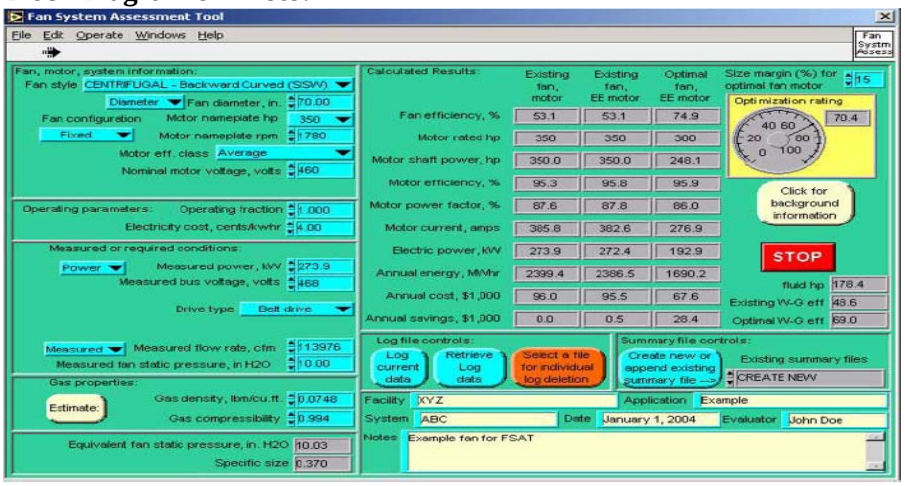


Figure 8.4: FSAT main data input screen

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.5 MotorMaster+ International – Cost-Effective Motor System Efficiency Improvement

Description:
MotorMaster+ International helps plants manage their motor inventory and make cost-effective decisions when repairing and replacing motor systems.

Based on site-specific user input and database information for typical motor functionality, the tool determines energy and cost savings for motor selection decisions by taking into account variables, such as motor efficiency at its load point, purchase price, energy costs, operating hours, load factor, and utility rebates.

Energy/Environment/Cost/Other Benefits:
- Analysis features allows for the selection of the best available motor for a given application, with the determination of demand reductions, greenhouse gas emission reductions, simple payback, cash flows, and after-tax rate of return on investment
- Allows to conduct economic analyses using various currencies and to insert applicable country or regional motor full-load minimum efficiency standards, and country-specific motor repair and installation cost defaults
- Software comprehensive database contains:
  - Available data for 60 Hz National Electrical Manufacturers Association (NEMA) and 50 Hz metric or International Electrotechnical Commission (IEC) motors
  - Over 25,000 NEMA motors and over 7,200 IEC motors
  - Ability to modify motor operating details in the database

Block Diagram or Photo:

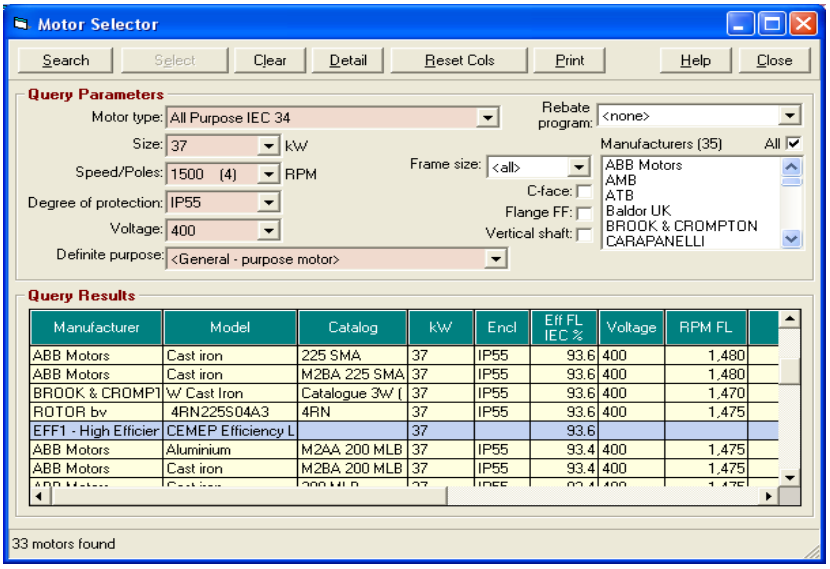


Figure 8.5: Screen shot of MotorMaster+ International interface

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.6 NOx and Energy Assessment Tool – Reduced NOx Emissions and Improved Energy Efficiency

Description:
The NOx and Energy Assessment Tool (N_xEAT) provides a systematic approach to estimate NOx emissions and analyze NOx and energy reductions methods and technologies.

N_xEAT allows plants to analyze the effects of NOx reductions methods and energy efficiency practices by providing equipment inventory and configuration information. The tool targets specific systems, such as fired heaters, boilers, gas turbines, and reciprocating engines to help identify the NOx and energy savings potentials associated with each option. The tool also provides calculators that aid in comparisons between options.

Energy/Environment/Cost/Other Benefits:
Based on inputted plant-specific information and the N_xEAT database, the tool creates a report presenting:

- Profile of plant's current NOx emissions, energy use, and annual energy cost for NOx-generating equipment
- Energy savings analysis
- Calculation and comparisons of NOx emissions and capital reduction for each analysis
- Table of charts of NOx and energy savings

Block Diagram or Photo:

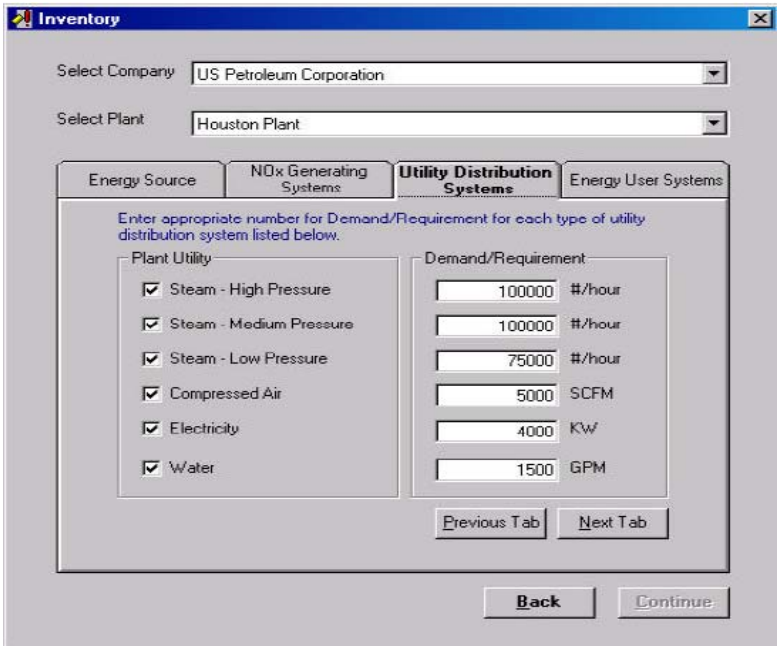


Figure 8.6: N_xEAT screen shot

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.7 Process Heating Assessment and Survey Tool – Identify Heat Efficiency Improvement Opportunities

Description:
The Process Heating Assessment and Survey Tool (PHAST) identifies ways to increase energy efficiency by surveying all process heating equipment within a facility, determining the equipment that use the most energy, and evaluating energy use under various operating scenarios.

Based on user input guided by the tool and a database of thermal properties, PHAST calculates energy use in specific pieces of equipment and throughout the process heating system. The output facilitates the identification and prioritization of efficiency improvements by suggesting methods to save energy in each area where energy is used or wasted, and by offering a listing of additional resources.

Energy/Environment/Cost/Other Benefits:
Capabilities of tool include:

- Calculation of potential savings
- Comprehensive equipment survey
- Determination of wasted energy
- Identified significant potential savings in a steel reheating furnace indicating that:
  - Fuel use could be reduced by approximately 30MM Btu/hour for the heating zone and 5MM Btu/hour for the soak zone
  - 2MM Btu/hour could be saved by reducing losses through openings
  - Total potential savings for the unit of 37MM Btu/hour, or 22% of all energy used by the furnace
  - Suggested low-cost improvements included better control of the air-fuel ratio and installation of radiation shields (curtains that eliminate radiation heat loss)

Block Diagram or Photo:

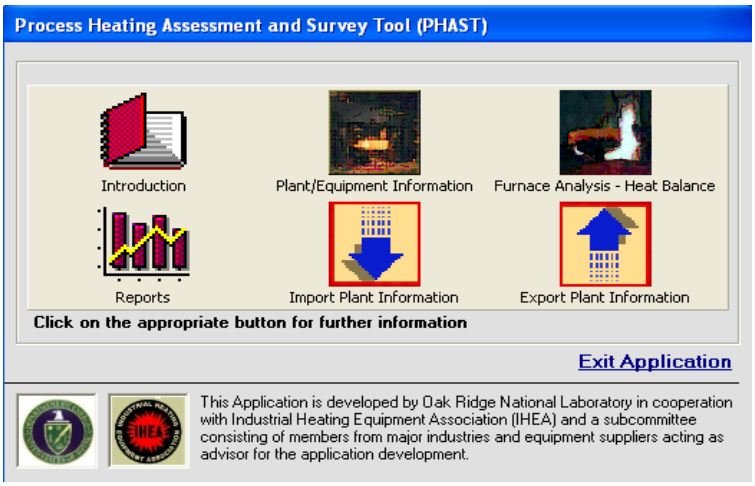


Figure 8.7: Screen shot of PHAST

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.8 Quick Plant Energy Profiler – First Step to Identify Opportunities for Energy Savings

Description:
Quick Plant Energy Profiler (Quick PEP), a free online software tool, helps facilities quickly diagnose their energy use and begin identifying opportunities for savings. Quick PEP uses basic information about major energy-consuming systems to create a report that profiles plant energy usage. The tool's output presents the energy usage for plant processes and identifies specific targeted ways to economically save energy and help reduce environmental emissions associated with energy production and use.

Energy/Environment/Cost/Other Benefits:
Capabilities of tool include:

- Details plant energy consumption
- An overview of energy generation, purchases, and associated costs
- Potential energy and cost savings
- Customized list of suggested 'next steps' to begin implementing energy-saving measures

Block Diagram or Photo:

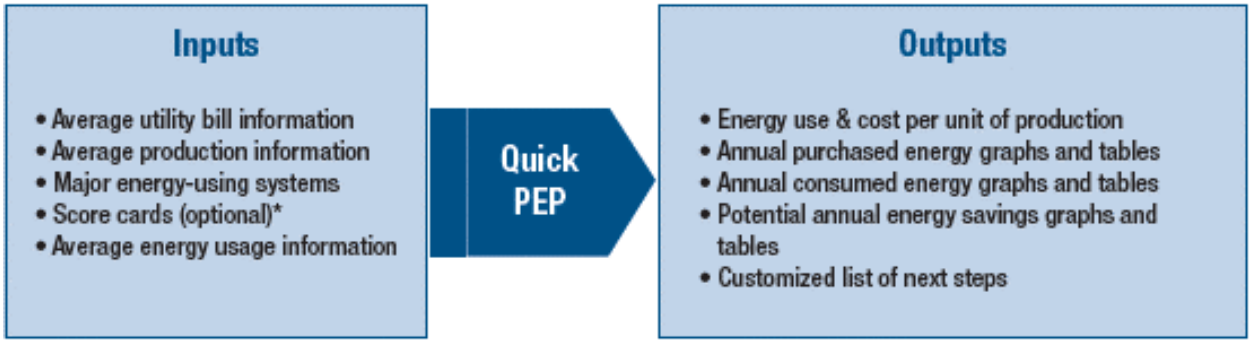


Figure 8.8: Quick PEP process flow diagram

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.9 Steam System Tools – Tools to Boost Steam System Efficiency

Description:
The following suite of software tools help enable facilities to evaluate steam systems and to identify opportunities for improvement.

Steam System Scoping Tool
This tool quickly evaluates the plant's entire steam system and spots areas that are the best opportunities for improvement, suggesting various methods to save steam energy and boost productivity. It profiles and grades steam system operations and management from user-inputted steam system operating practices, boiler plant operating practices, and distribution and recovery practices, and then compares user's steam system operations against identified best practices.

Steam System Assessment Tool
The Steam System Assessment Tool (SSAT) develops approximate models of real steam systems to quantify the magnitude (energy, cost, and emission savings) of key potential steam improvement opportunities. SSAT contains all the key features of typical steam systems – boilers, backpressure turbines, condensing turbines, deaerators, letdowns, flash vessels, and feed water heat exchangers.

The tool analyzes boiler efficiency, boiler blowdown, cogeneration, steam cost, condensate recovery, heat recovery, vent steam, insulation efficiency, alternative fuels, backpressure turbines, steam traps, steam quality, and steam leaks. Its features include a steam demand savings project, a user-defined fuel model, a boiler stack loss worksheet for fuels, and a boiler flash steam recovery model.

3E Plus
3E Plus calculates the most economical and energy efficient industrial insulation thickness for user-inputted operating conditions in order to conserve energy and avoid over-insulation expenses.
Users can utilize built-in thermal performance relationships of generic insulation materials or supply conductivity data for other materials.

Energy/Environment/Cost/Other Benefits:
Steam system tools allow the user to evaluate what-if scenarios for the following key improvement opportunities:

- Boiler efficiency/blowdowns
- Utilizing back pressure turbines to let down steam
- Steam trap operating efficiencies
- Vent steam
- Cogeneration Opportunities
- Condensation recovery
- Alternate Fuels
- True cost of steam
- Heat recovery
- Steam leaks
- Steam quality
- Insulation efficiencies

Block Diagram or Photo:

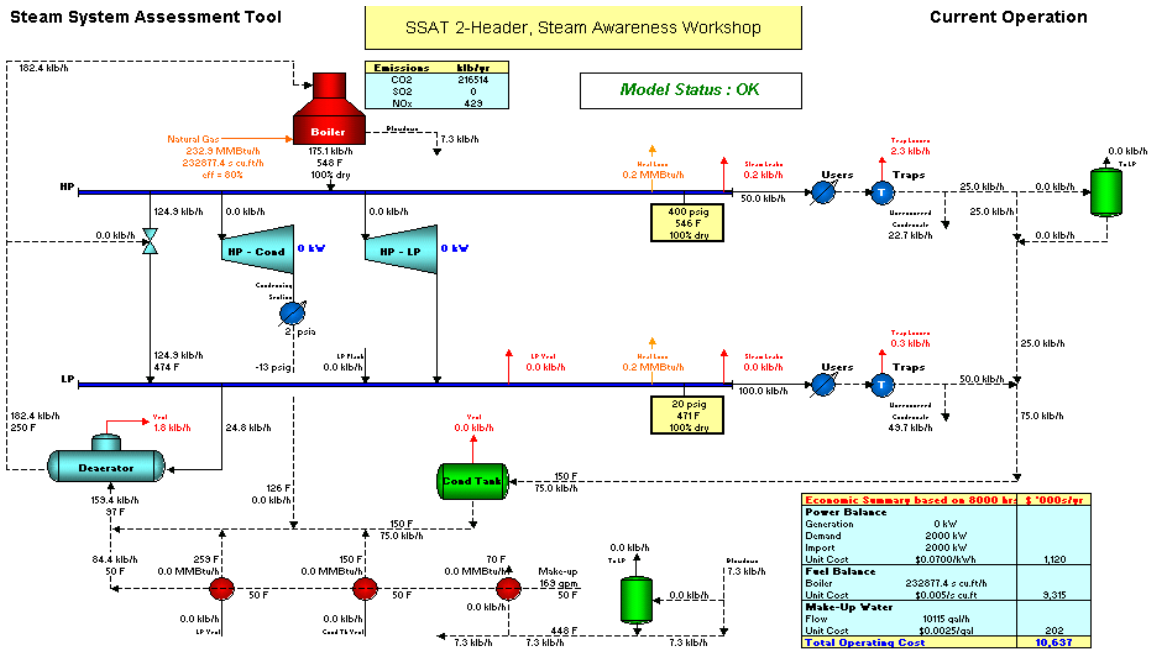


Figure 8.9: Model diagram of Steam System Assessment Tool

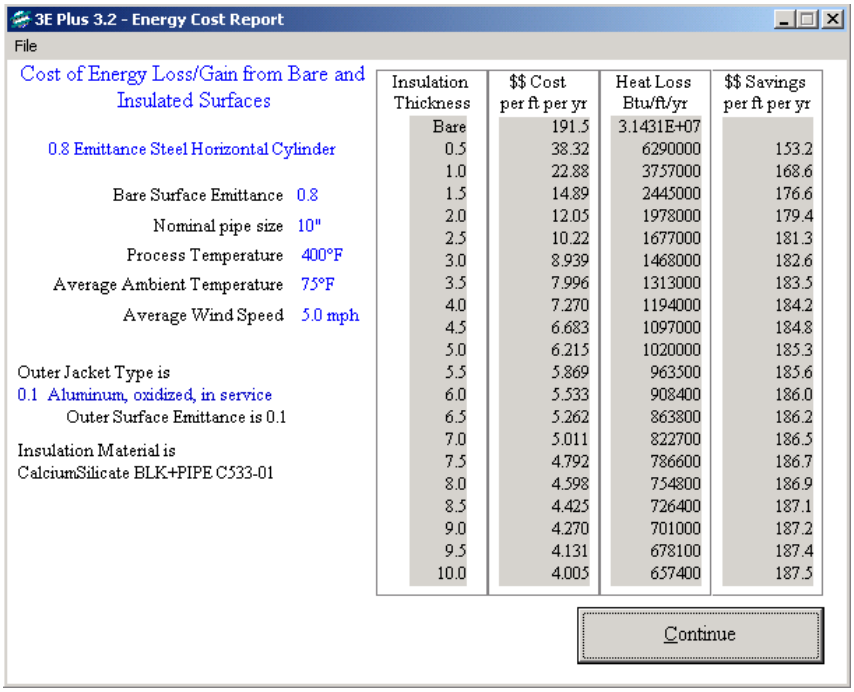


Figure 8.10: Screen shot of 3E Plus

Commercial Status: Mature

Contact information:
US DOE Industrial Technologies Program
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.10 Variable Speed Drives for Flue Gas Control, Pumps and Fans

Description:
Variable speed drives (VSDs) better match speed to load requirements for motor operations. VSD systems are offered by many suppliers and are available worldwide.

Energy/Environment/Cost/Other Benefits:
- Based on experience in the UK:
  - Electricity savings of 42% are possible through the use of VSDs on pumps and fans year[67]
  - Payback of 3.4 years, assuming an electricity price of 3pence/kWh, under U.S. 1994 conditions[68]
  - Costs of $1.3/t product

Block Diagram or Photo:



Figure 8.11: VSD on 300-hp boiler draft fan

Commercial Status: Mature

Contact information:
None available.

[67] Anonymous, 1994. "Energy Saving VSD Quench Pumps," Steel Times, April: 150.
[68] International Energy Agency, 1995. *Energy Prices and Taxes, First Quarter 1995*, Paris: IEA.

8.11 Regenerative Burner

Description:
A regenerative burner is a heat recovery system that recovers the waste heat of the furnace exhaust gas to heat-up the combustion air of the furnace. The regenerative burner uses heat reservoirs and dual heat-recovering generators at each burner to channel heat more efficiently. During combustion, one side of a burner combusts fuel while the other accumulates the exhaust heat into the heat-recovering generator. Then the burners switch so that the one accumulating heat combusts the fuel and the other now accumulates exhaust heat.

Energy/Environment/Cost/Other Benefits:
- 20-50% of energy reduction possible, depending on types of furnace and condition of fuel
- Up to 50% NOx reduction possible with high temperature combustion
- Excellent operational reliability, with introduction of regenerative burner systems in over 540 furnaces in various Japanese industries

Block Diagram or Photo:

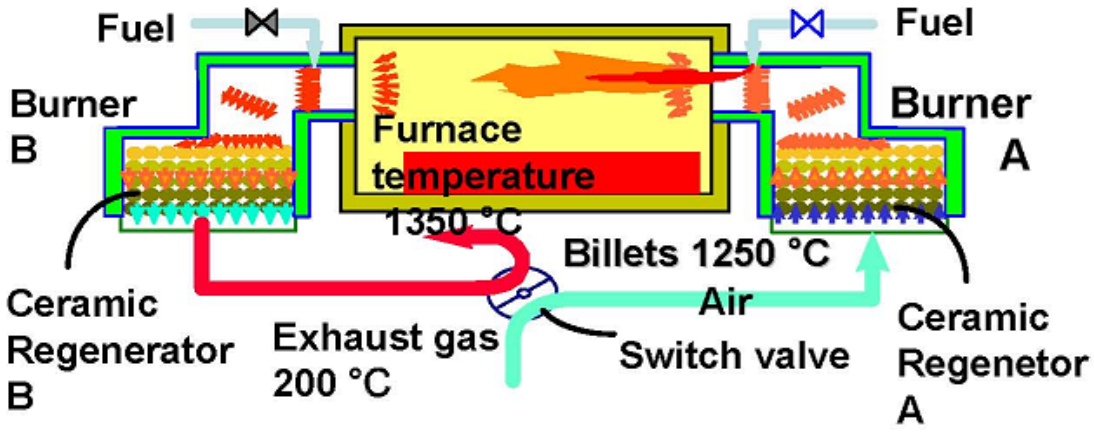


Figure 8.12: Application of regenerative burner

Commercial Status: Mature

Contact information:
JFE Steel Corporation
http://www.jfe-steel.co.jp/
Japan Iron and Steel Feferation (JISF)
http://www.jisf.or.jp

9 General Energy Savings & Environmental Measures

9.1 Energy Monitoring and Management Systems

Description:
This measure includes site energy management systems for optimal energy recovery and distribution between various processes and plants. A wide variety of such energy management systems exist[69,70].

Energy/Environment/Cost/Other Benefits:
- Tata Iron and Steel Company (formerly Hoogovens, The Netherlands and British Steel, Port Talbot, UK):
  - Energy savings estimated to be 0.5% or fuel savings of 0.12 GJ/t of product and electricity savings of 0.01 GJ_e/t of product[71,72]
  - Costs estimated to be approximately $0.15/t crude steel based on $0.8M for the system in the Netherlands[71]

Block Diagram or Photo:

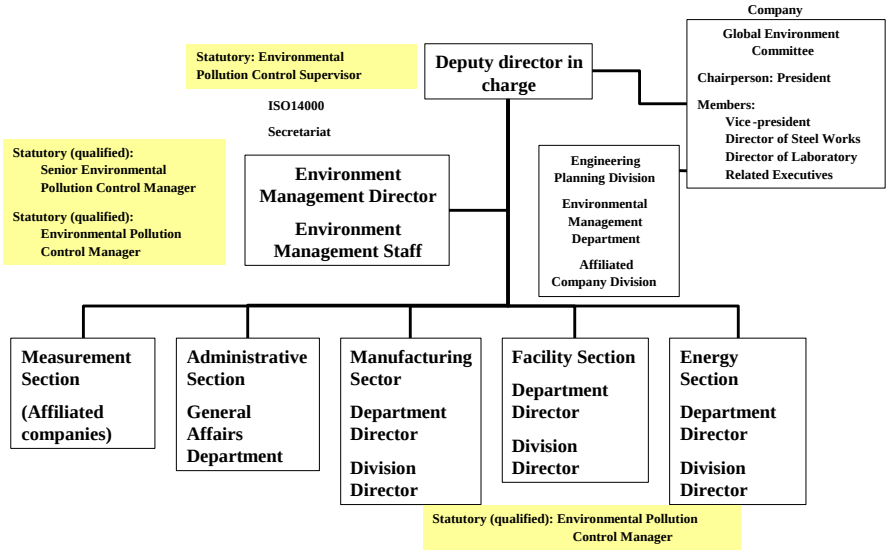


Figure 9.1: Environmental management system at steel works organizational chart

Commercial Status: Mature

Contact Information: Not available

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[69] Worrell, E. and C. Moore, 1997. "Energy Efficiency and Advanced Technologies in the Iron and Steel Industry," in: Proceedings 1997 ACEEE Summer Study on Energy Efficiency in Industry, Washington, DC: ACEEE.
[70] Caffal, C., 1995. "Energy Management in Industry," CADDET Analyses Series 17, Sittard, The Netherlands: Caddet.
[71] Farla, J.C.M., E. Worrell, L. Hein, and K. Blok, 1998. Actual Implementation of Energy Conservation Measures in the Manufacturing Industry 1980-1994, The Netherlands: Dept. of Science, Technology & Society, Utrecht University.
[72] ETSU, 1992. "Reduction of Costs Using an Advanced Energy Management System," Best Practice Programme, R&D Profile 33, Harwell, UK: ETSU

9.2 Cogeneration

Description:
All plants and sites that need electricity and heat (i.e. steam) in the steel industry are excellent candidates for cogeneration. Conventional cogeneration uses a steam boiler and steam turbine (back pressure turbine) to generate electricity. Steam systems generally have a low efficiency and high investment costs. Current steam turbine systems use the low-cost waste fuels, which may have been vented before, e.g., Arcelor Mittal and US Steel Gary Works in the United States[73]. Modern cogeneration units are gas turbine based, using a simple cycle system (gas turbine with waste heat recovery boiler), a Cheng cycle or STIG (with steam injection in the gas turbine), or a combined cycle integrating a gas turbine with a steam cycle for larger systems. The latter system can also be used to're-power' existing steam turbine systems. Gas turbine systems mainly use natural gas. Integrated steel plants produce significant levels of off-gases (coke oven gas, blast furnace gas and basic oxygen furnace-gas). Specially adapted turbines can burn these low calorific value gases at electrical generation efficiencies of 45% (low heating value), but internal compressor loads reduce these efficiencies to 33%[74]. Mitsubishi Heavy Industries has developed such a turbine and it is now used in several steel plants, e.g., Kawasaki Chiba Works (Japan)[75] and Tata Iron and Steel Company (formerly Hoogovens, The Netherlands)[76]. Given the low level of steam demand in secondary steel making plants, most of the cogeneration would apply to integrated facilities.

Energy/Environment/Cost/Other Benefits:
- Increased electricity generation of 1.1 GJ/t crude steel (primary energy)
- Investments for turbine systems are $1090/kWe[76]. Total investment costs estimated to be $14.5/t crude steel.
- Low NOx emissions of 20 ppm[74].

Block Diagram or Photo:



Figure 9.2: Gas turbine systems

Commercial Status: Mature

Contact Information: Not available

---

[73] Hanes, C., 1999. USS/Kobe Steel, Personal communication, June 1999.
[74] Mitsubishi Heavy Industries, 1993. High Efficiency From Low BTU Gas, Outline of 145 MW Combined Cycle Power Plant for Kawasaki Steel Corporation, Chiba Works, Mitsubishi Heavy Industries, Ltd., Tokyo, Japan.
[75] Takano, H., Kitauchi, Y., and Hiura, H., 1989. Design for the 145 MW Blast Furnace Gas Firing Gas Turbine Combined Cycle Plant," Journal of Engineering for Gas Turbines and Power, 111 (April): 218-224.
[76] Anonymous, 1997c. "Warmtekrachteenheid van 144 MWe bij Hoogovens" Energie en Milieuspectrum, October 1997, p.9.

9.3 Technology for Effective Use of Slag

Description:
Slag can be employed for various end uses outside of steel making:
- Converting slag as a purification catalyst can help restore ecosystems in water areas.
- In concrete and as a low-quality aggregate
- For land improvement

Energy/Environment/Cost/Other Benefits:
- Slag usage in marine applications is a new field with huge potential for shoreline improvement and restoration of lost shallows and seaweed beds
- Using BF slag in cement manufacturing helps to reduce energy use by eliminating granulation and heating [340 kg-CO_2/t slag]

Block Diagram or Photo:
None available

Commercial Status: Emerging or commercial:
Converting slag for marine usage is emerging
Use of slag in the cement industry is commercial.

Contact Information:
Japan Iron and Steel Federation

9.4 Hydrogen Production

Description:
Coke oven gas (COG), a byproduct gas of the iron-making process, contains around 55% hydrogen. It is easy to produce hydrogen with high purity from COG by a very simple process called pressure swing adsorption (PSA). Significant efforts to recover sensible heat of COG as hydrogen enrichment are under way. Developing proper catalysts is the key to success.

Energy/Environment/Cost/Other Benefits:
- Hydrogen is expected to be an important energy carrier for fuel cells
- Because of its ease of production, its abundance, and its distribution, COG is one of the major candidates for a hydrogen source in the future

Block Diagram or Photo:

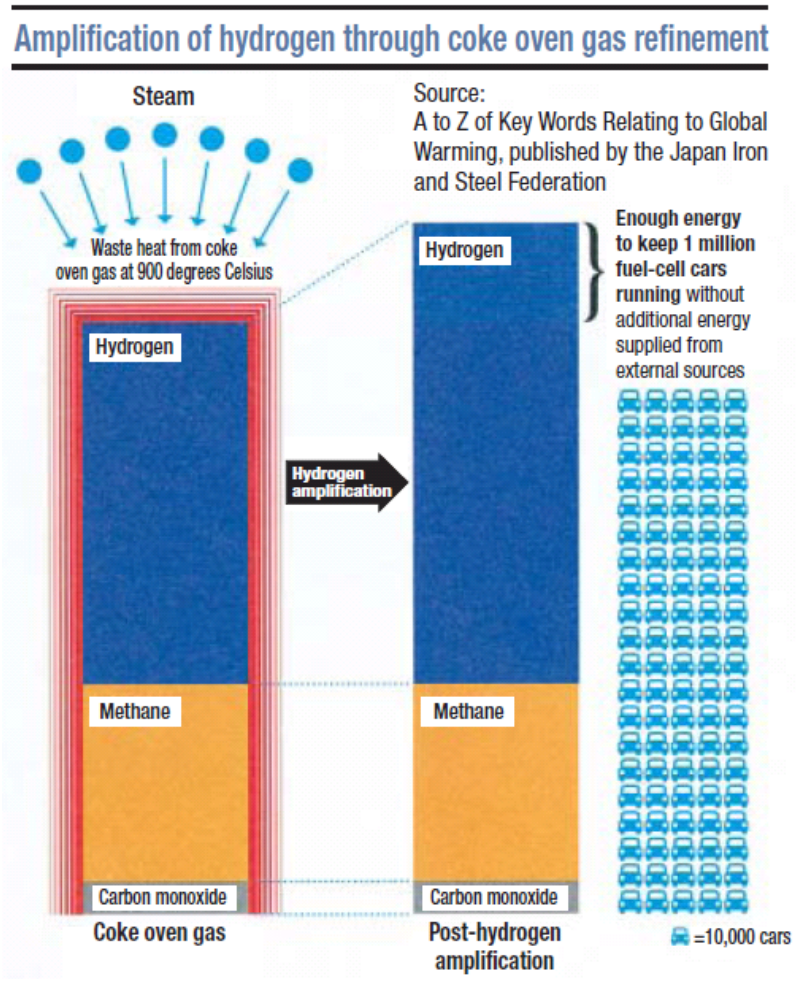


Figure 9.3: High-efficiency hydrogen production technology

Commercial Status: Emerging

Contact Information:
Japan Iron and Steel Federation, "The Voluntary Action Program of JISF"

9.5 Carbonation of Steel Slag

Description:
Carbonates of steel slag are formed when slag solidifies by absorbing CO_2. This sequesters the CO2 in the slag, which can then be used in marine applications.

Energy/Environment/Cost/Other Benefits:
- Steel slag carbonates can be used to make "marine blocks" which can improve the coastal environment by helping to grow seaweed [which improves sea surroundings]
- Marine blocks are also used for coral nursery beds, which may help to revive dead coral areas

Block Diagram or Photo:

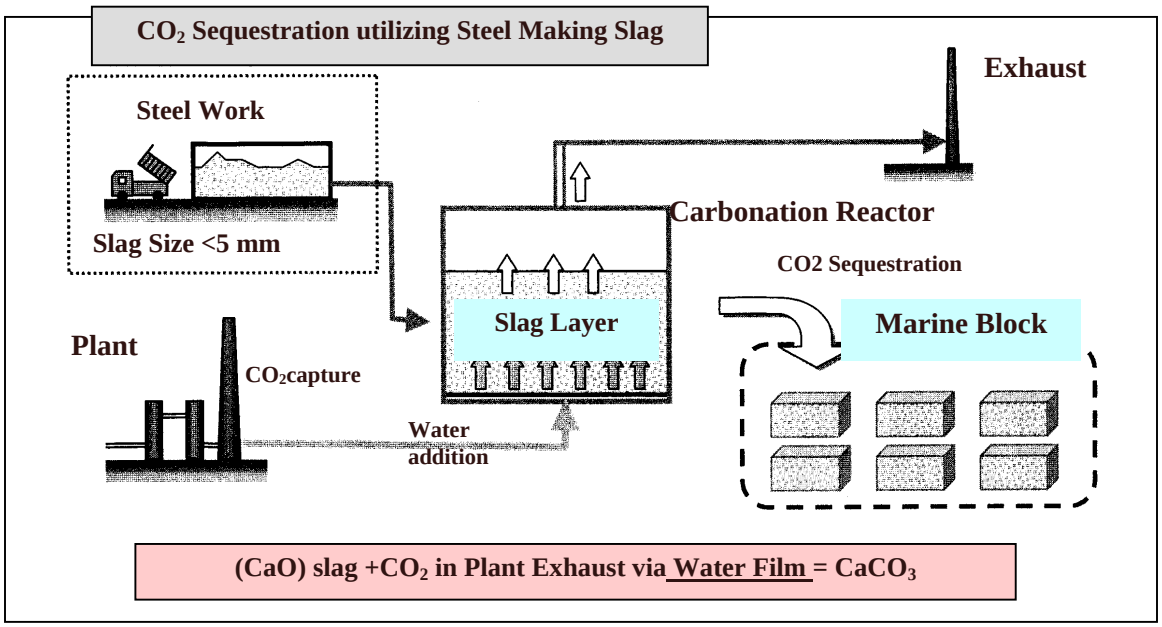


Figure 9.4: Reduction of CO_2 in exhaust gas by carbonation of steelmaking

Commercial Status: Emerging

Contact Information:
Japan Iron and Steel Federation, "The Voluntary Action Program of JISF"

Appendix 1 (Summary Technologies Submitted)

1.1.4 Exhaust Gas Treatment through Denitrification, Desulfurization, and Activated Coke Packed Bed Absorption

Japan: State-of-the-Art Clean Technologies for Sintering Emissions Control

Emissions Control by Activated Coke Method

Process Characters:

SOx, Nox, Dust and Dioxins in exhaust gas from sintering machines are effectively removed by the activated coke method.

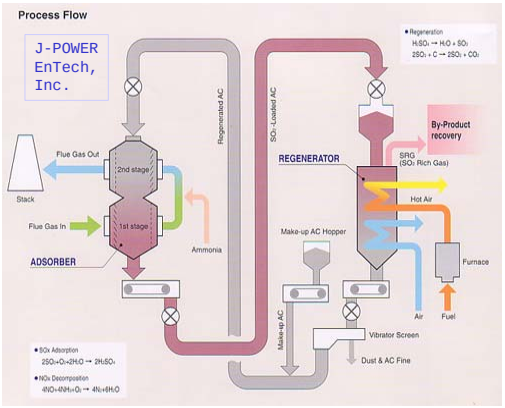
SOx is absorbed in activated coke and is recovered as by-product.

Nox is decomposed to nitrogen, water and oxygen by ammonia.

Dust is collected in activated coke.

Dioxins are collected or absorbed in activated coke and are discomposed at 400C under no-oxygen.

Contact:
J-POWER EnTech, Inc.
http:/www.jpower.co.jp/entech/



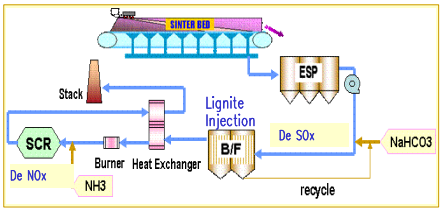
1.1.5 Exhaust Gas Treatment through Selective Catalytic Reduction

Republic of Korea: State-of-the-Art Clean Technologies for Sinter Flue gas Treatment

Selective Catalystic Reduction

Description:

SOx and Dioxin contained in Sinter flue gas will be removed by adding sodium bi-carbonate and Lignite. NOx will be removed NOx by selective catalytic reduction reaction,($4NO + 4NH_3 + O_2$? $4N_2 + 6H_2O$) at around 200~450 ?.



De SOx : $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$ (T>140°C)
$Na_2CO_3 + 2SO_2 + 1/2O_2 \rightarrow Na_2SO_4 + 2CO_2$

De NOx : $NOx + NH_3 \rightarrow N_2 + H_2O$

Lignite Injection: Dioxin < 0.2 ng-TEQ/Nm³

Core Technology
- **Catalyst maintenance**
- Corroson prevention.
- **Operating technology**

Benefits
- **High SOx, NOx removal efficiency**

Commercialization: Emerging
- **Full scale facility is being installed in Kwangyang works: 4 units**
(completion: June 2007)

Contact
Mr. Youngdo Jang
Dept. Environmet& Energy, POSCO
T +82-54-220-5773
ydjang@posco.co.kr

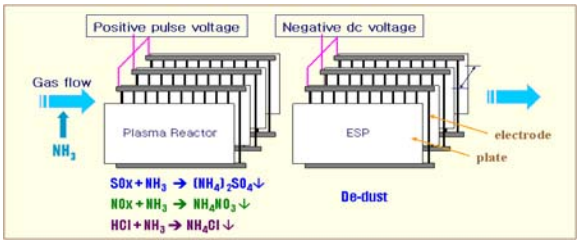
1.1.6 Exhaust Gas Treatment through Low-Temperature Plasma

Republic of Korea: State-of-the-Art Clean Technologies for Sinter Flue gas Treatment

Low-Temperatute Plasma

Description :

Active radicals of low-temperature plasma remove SOx, NOx, and HCl simultaneously with significant efficiency. Commercial scale plant installed at an incinerator in Kwang works, showed a substantial reduction of SOx(>70%), NOx(>95%) and HCl(>99%) respectively.
Dioxin also decreased (<0.2 ng-TEQ/Nm³) with the addition of Lignite in the process. Its reliability as well as the stability have been proved through the operation more than 5 years.
POSCO plans to adopt above technology at #2 Sinter plant in Pohang Works.





Core Technology
- **MPC design**
  - Full scale Magnetci Pulse Compressor Design
- **Pulse stabilizing technology**
  - Stabilizing pulse width & rising time
- **Reactor Design technology**
  - Proper reactor capacity design
- **Energy saving technology**
  - Adding additives

Benifits
- **Lower Cost with high pollutants removal effciency**
  - Investment & Running cost
- **More compactive**
  - Less space required

Commercialization: Demonstration
- **First pilot facility constructed in 1996.**
- **Installation of commercial scale plant in 2000**
  - Kwanyang Works: Incinerator
- **Future Plan**
  - Pohang Works: 1Unit for Sinter Plant (~2010)

Contact
Mr. Youngdo Jang
Dept. Environmet& Energy, POSCO
T +82-54-220-5773
ydjang@posco.co.kr

1.1.8 Segregation of Raw Materials on Pellets, &
1.1.9 Multi-slit Burner Ignition Furnace

Japan: State-of-the-Art Clean Technologies for Sintering Energy Saving

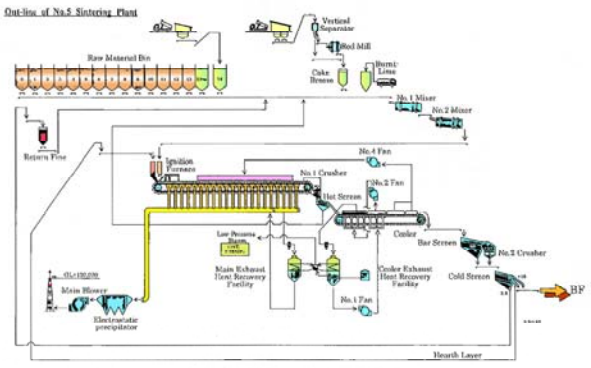
Energy Saving in the Sintering Process

Operational Aspects:

Segregation and granulation reinforcement of raw materials on sintering pellets are effective to improve permeability and decrease return rate to sintering pellets, and consequently increase productivity and save energy.

Equipment Aspects:

Multi-slit burners in ignition furnace and heat recovery from Cooler are effective. Steam generated by heat recovery is used as steam and/or is used to generate electric power. This heat recovery accounts for approximately 30% of total heat input.



Contact:

Sumitomo Metal Industries,LTD.
http://www.sumitomometals.co.jp/

JP Steel Plantech.Co.
http:/www.steelplantech.co.jp/

1.1.11 Biomass for Iron and Steelmaking

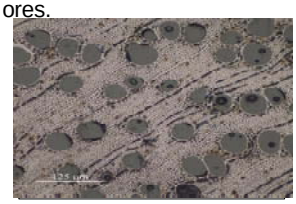
Australia: State-of-the-Art Clean Technologies for Iron and Steelmaking

Biomass for Iron and Steelmaking

CSIRO Minerals is working with the industry and collaborative research partners to develop biomass utilisation practices for iron and steelmaking.

Wood char has been shown to be a suitable replacement for coke breeze in the sintering process, resulting in process improvements and the reduction of acid gas levels in process emissions.

Charcoal has been found to be as effective a fuel and reductant as high rank coals for the bath smelting of iron ores.



Microstructure of eucalypt hardwood charcoal used for metallurgical testing.



Injection of charcoal into a molten iron bath at CSIRO Minerals.

Benefits

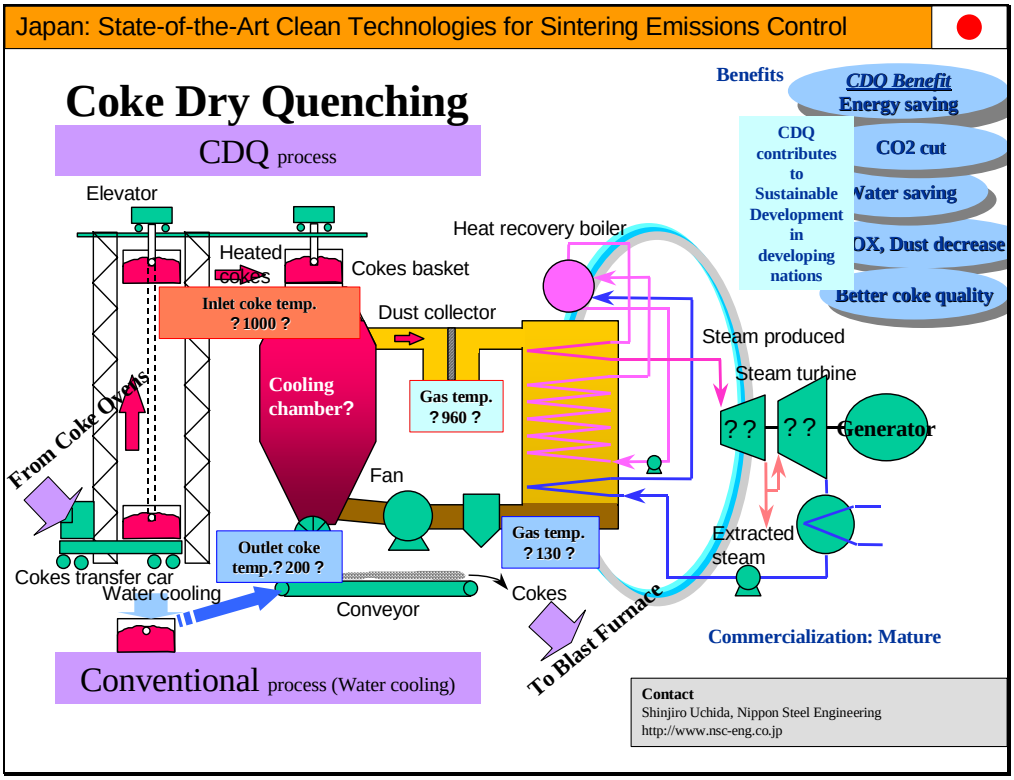
- **Substantial reductions in CO_2 emissions**
- **Reductions in acid gas emissions**
- **Improved carburisation rates and increased product quality**
- **Reduced demand for fluxing agents**
- **Lower slag volume and levels of process wastes**
- **Higher productivity through use of more reactive carbon.**

Commercialisation: **Demonstration**

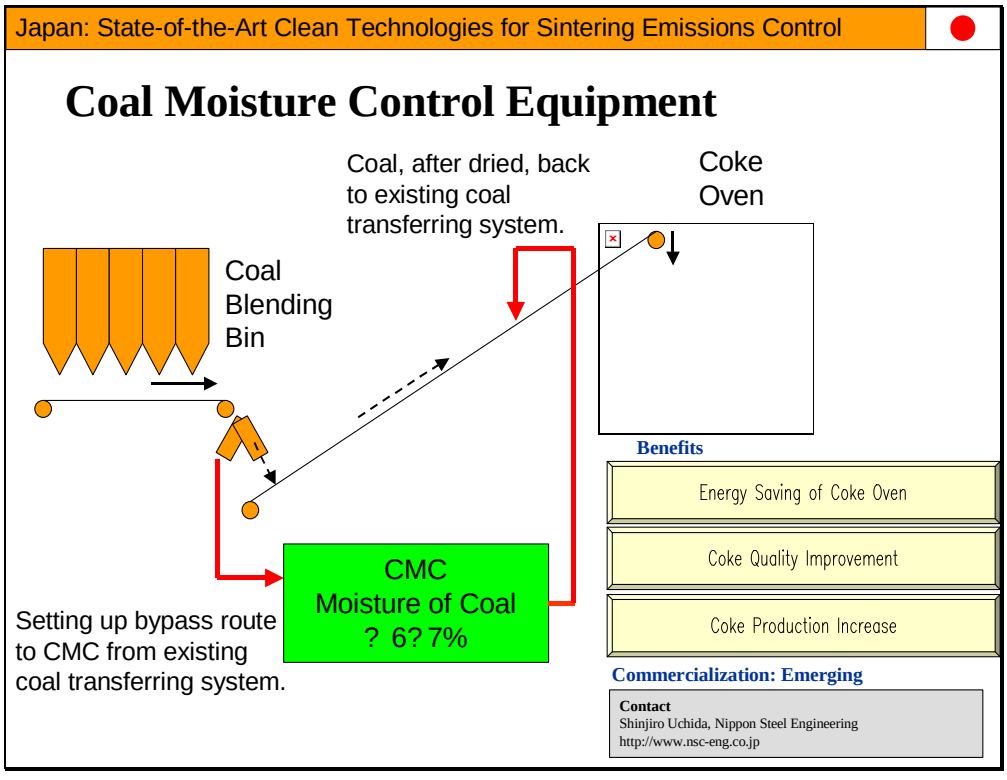
- **Key equipment – fully instrumented pilot plants for sintering and bath smelting**
- **History of close interaction with industry for process development.**
- **Advanced mathematical models for process simulation and evaluation**

Contact:
Sharif Jahanshahi
www.**minerals.csiro**.au

2.2 Coke Dry Quenching



2.3 Coal Moisture Control



3.1.1 Top Gas Pressure Recovery Turbine

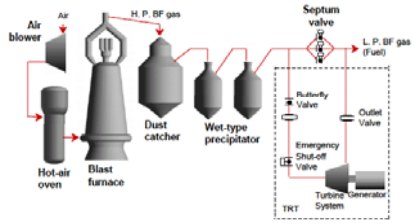
Japan: State-of-the-Art Clean Technologies for Ironmaking

Top gas pressure Recovery Turbine (TRT)

Power Generation from Blast Furnace Gas Pressure

TRT is the power generation system, which converts physical energy of high pressure blast furnace top gas into electricity by using expansion turbine.

The key technology of TRT is to secure stable and high-efficiency operation of expansion turbine in dusty blast gas condition without harmful effect to blast furnace operation. Since the first commercial operation of 1974, introduction of TRT was accelerated and now, TRT is installed all the operating blast furnace in Japan.



Flow diagram for the TRT system (wet type)



Photo:

Axial Flow type TRT

Benefits

- **Energy** – Approximately, electricity of 40 to 60 kWh per ton-pig iron can be generated by TRT. At present, more than 8% of electricity,which is consumed in Japanese Integrated Steel Works, is generated by TRT.
- **Environment** – Power Generation by TRT can reduce power generation of thermal power plant, which is connected to the grid. Therefore, fossil fuel consumption of thermal power plant can be reduced.
- **Reliability** – Excellent operational reliability. All the blast furnace in Japan has already introduced TRT.

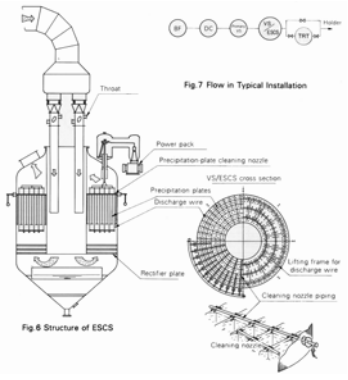
Commercialization: Mature

- First commercial facility constructed in 1974.

Contact
1. KAWASAKI HEAVEY INDUSTRIES, LTD.
http://khi.co.jp/products/gendou/ro/ro_01.html
2. MITSUI ENGINEERING & SHIPBUILDING CO., LTD.
http://mes.co.jp/business/english/energy/energy_10html

Japan: State-of-the-Art Clean Technologies for Sintering Emissions Control

TRT + VS-ESCS



Benefits

1. Substantial increase in energy recovery by TRT (Pressure loss : 700mmAq or less)
2. Higher temp. gas can be treated compared with Bag filter system
3. ESCS can be installed in the existing 2nd VS and lower investment compared with Bag filter system
4. Lower water consumption compared with other wet type

Commercialization: Emerging

Contact
Shinjiro Uchida, Nippon Steel Engineering
http://www.nsc-eng.co.jp

3.1.2 Pulverized Coal Injection (PCI) System

Japan: State-of-the-Art Clean Technologies for Sintering Emissions Control

Pulverized Coal Injection (PCI) System

Pulverized Coal Injection (PCI)

Introduction of PCI

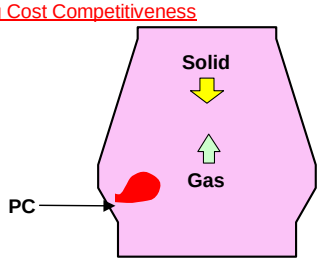
⇩

Decrease of Coke rate

⇩

Cost reduction of Hot metal

Improving Cost Competitiveness



Benefits

1. Cost Saving by Less Frequency of BF Relining
2. Cost Saving by Higher Productivity with Same BF
3. Cost Saving from Daily Operation

Advantages of the system

- Uniform Transfer of Pulverized Coal
- No Moving Part in Injection Equipment
- Natural Even Distribution to the Tuyeres

⇩

High Reliability & Easy Operation

Commercialization: Mature

Contact
Shinjiro Uchida, Nippon Steel Engineering
http://www.nsc-eng.co.jp

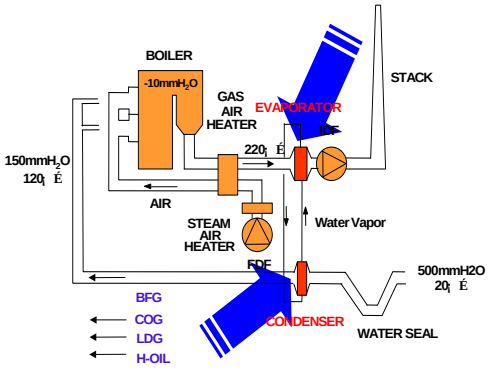
3.1.3 Blast Furnace Heat Recuperation

Republic of Korea: State-of-the-Art Clean Technologies for BFG preheating System

BFG Preheating System

Using waste heats of low and medium temperature grade

BFG preheating system uses waste heats of low and medium temperature grade (220~170 ℃). It is not easy to exchange heats due to corrosion. Loop thermosyphon is the most economic device for recovering waste heats of low and medium temperature grade in the steel industry. For the case of boiler, 3~5% of energy saving has been achieved and the pay-back period was within 1.5 years. Its reliability as well as the stability have been proved through the operation more than 10 years.



Core Technology

- **Anti-corrosion technology (SOx, NOx)**
  - High surface temperature
- **Minimize pressure drop**
  - Fin shape and tube arrangement
- **Closed loop thermosyphon system design**
  - Overall heat transfer coefficient
- **Operating technology**

Commercialization: Emerging

- First commercial facility constructed in 1997.
- Installation of BFG preheating system
  - Pohang Works: 5 Unit
  - Gwangyang Works: 9 Unit
- Future Plan
  - Pohang Works: 2 Unit (~2008)

Contact
Mr. Yun-Sik Jung
Pohang Works, POSCO
T +82-54-220-4579
yswilly@posco.co.kr

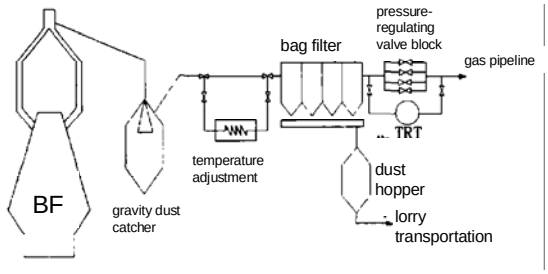
3.1.5 Blast Furnace Gas and Cast House Dedusting

China: State-of-the-Art Clean Technologies for energy saving

DRY-TYPE DEDUSTING TECHNOLOGY FOR BF GAS

➢Dry type dedusting is a technology which employs electro-precipitator or bag filter to clean the BF gas. The conventional BF gas cleaning system consists of a gravity dust catcher and 2-stage venturi scrubber. Venturi scrubber is of wet-type cleaning unit which has a complicated structure and consumes large amount of water. The dry-type dedusting system however, does not request water scrubbing, thus can largely save the valuable water resources. In addition, electric energy recovery can be increased approximately by 30% with TRT system due to the higher temperature and large volume of BF gas.

➢BF gas dry-type dedusting is an effective and important overall energy saving and environmental protection technology. It will be of great significance to the sustainable development of China's steel industry and enhancement of our competitiveness along with the widely promotion of this new technology in the blast furnaces nationwide.



Benefits

- **Energy** –30% more power generated with dry-type TRT than wet-type TRT, showing evident energy –saving result?

reduction of recirculated water consumption:7? 9Nm³/tHM, of which 0.2m³ fresh water. Besides, investment and land area are also saved for constructing the large-sized water scrubber, settlement tank and so on. In the meantime generation of polluted water and slurry are eliminated as well.

- **Environment** –dust content in cleaned gas? 5mg/Nm³, thus remarkably improves the gas cleanness and benefits environmental protection. The noise level up to 140 dB can be reduced below 85 dB which effectively minimizes the noise pollution.
- **Occupied land area:** 50% less than that for wet-type process, so that the land occupation is minimized.
- **Investment:** only account for 70% in investment compared with wet-type process. It can minimize the investment and accelerate the project construction

Commercialization: Emerging

- Laiwu Iron & Steel Corp (Group) which acts as the technical backup is the first one in China to develop and utilize this dry-type dedusting technology in large- and medium sized blast furnaces and owns intellectual property right in number of proprietary technologies.
- The number of blast furnaces totals 785 in China for the time being, of which nearly 300 furnaces are bigger than 1000 m³, so there is a broad prospect in promotion of this technology.

Contact

3.3.1 Smelting Reduction Processes

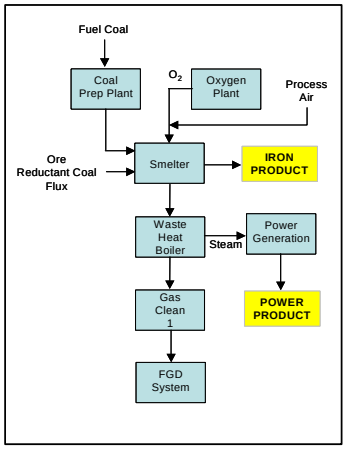
Australia: State-of-the-Art Clean Technologies for Iron and Steelmaking

Ausmelt Ausiron® Technology

Bath smelting iron production for the supply of high-quality hot metal and pig iron for use by both integrated and EAF-based steel producers. Ausmelt offers facilities that benefit steel producers through the use of low-cost feed materials, and recycling of steel plant by-products.



Iron production at the Ausiron demonstration facility, in South Australia.



Typical plant flowsheet.

Benefits:

- Adapted from a widely-used bath smelting process
- Direct use of iron ore fines & steel plant dusts
  no sintering or pelletizing
- Direct use of thermal coals
  reduced coal supply costs
- Single furnace with direct waste energy recovery
  low installation costs
- Environmentally robust iron production
  reduced emissions

Commercialisation: Emerging

Smelting technology currently used in 26 non-ferrous metals production facilities. Proven for iron production at a purpose-built demonstration facility between 2000 and 2003.

Contact
Ausmelt Limited
www.**ausmelt**.com.au

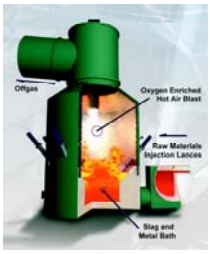
Australia: State-of-the-Art Clean Technologies for Iron and Steelmaking

HIsmelt® Direct Smelting Technology

HIsmelt is a direct smelting technology which smelts iron ore fines and non coking coals to produce a premium grade iron.

The HIsmelt technology can replace blast furnaces or provide low cost high quality iron units (as pig iron or hot metal) to the electric arc steelmaking industry.

It is positioned to become the technology of choice for future ironmaking requirements.



HIsmelt Process in Smelt Reduction Vessel



HIsmelt plant with pre-heater

Benefits

- Eliminates the need for coke ovens and sinter plants
- Greater flexibility in the range of raw materials acceptable as feedstocks, including steel plant wastes and high phosphorus ores
- Low capital and operating costs
- Environmental benefits – reduced CO_2, SO_2 and NO_x
- Produces a high quality iron product
- Can be scaled to replace blast furnaces of all sizes.

Commercialisation: Emerging

- An 0.8 Mtpa commercial plant has been built at Kwinana, Western Australia
- It is currently producing iron as it undertakes 3 year ramp-up to name plate capacity
- Advanced engineering for a 2 Mtpa facility being undertaken.

Contact:
HIsmelt Corporation Pty. Ltd.
www.**hismelt**.com.au

3.3.3 ITmk3® Ironmaking Process

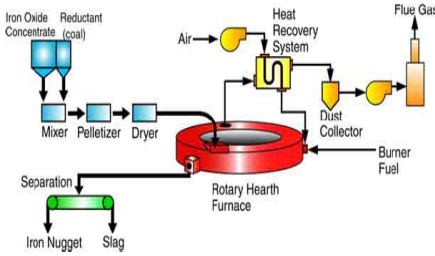
United States: State-of-the-Art Clean Technologies for Ironmaking

ITmk3® Ironmaking Process

High-Quality Iron Nuggets Produced From Low-Grade Ore

The ITmk3® process uses low-grade ore to produce iron nuggets of superior quality to direct reduced iron and similar quality to pig iron, suitable for use in electric arc furnaces, basic oxygen furnaces and foundry applications.

Developed by Kobe Steel of Japan, the ITmk3® process uses a rotary hearth furnace to turn low-grade iron ore fines and pulverized coal into high nugget purity (97% iron content). Reduction, melting, and slag removal occur in just 10 minutes.



Flow diagram for the ITmk3® process illustrates the one-step furnace operation



Iron nuggets from the pilot plant

Benefits

- **Energy** – Potential 30% energy savings over current 3-step integrated steelmaking; 10% savings for EAF steelmaking. All chemical energy of coal is utilized and no gas credit is exported.
- **Environment** – Allows higher scrap recycling in EAF through production of high purity nuggets. Eliminates coke oven or agglomeration plant; typical blast furnace can reduce emissions by more than 40%.
- **Quality** – Allows BOF to produce flat products of high quality steel due to dilution of tramp elements.
- **Reliability** – Excellent operational reliability. Reduces FeO to less than 2%, minimizing attack to refractories.

Commercialization: Emerging

- First commercial facility constructed in 2005.
- Two or more production facilities planned, totaling over 1.6 million tons/year capacity.

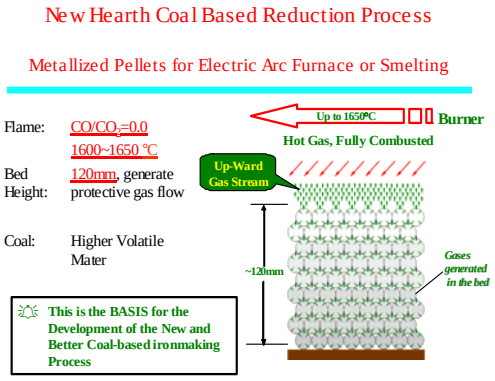
Contact
Mesabi Nugget, LLC
http://mesabinugget.com

3.3.4 Paired Straight Hearth Furnace

United States – Best Available Technologies for Direct Ironmaking

Paired Straight Hearth Furnace

The Paired Straight Hearth Furnace is a new coal-based reduction process for making metallized pellets for Electric Arc Furnace or Smelting processes. It operates at higher production rates and lower energy utilization than conventional rotary hearth processes.



Benefits

- High productivity with lower energy consumption than rotary processes [carbon is a reductant and the CO evolved in combustion is used as fuel] The tall bed is a key design factor which greatly increases productivity and protects the bed from reoxidation, enabling more complete combustion.
- When used as a pre-reducer with a smelter, enables higher productivity smelting operations to the point the combined process is a suitable Blast Furnace/Coke Oven replacement using 30% less energy at lower capital cost
- Coal is used without requiring gasification

Commercialization

- Emerging

Contact

- American Iron and Steel Institute
  http://www.steel.org

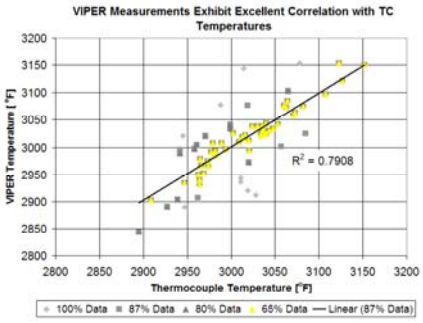
4.2.6 VIPER Temperature Monitoring System

United States – Best Available Technologies for EAF Steel making*

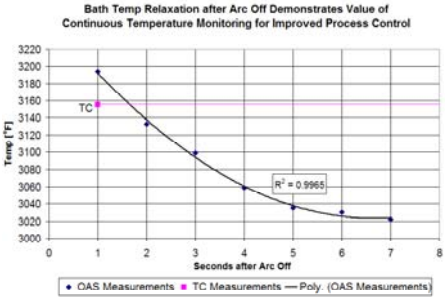
VIPER Temperature Monitoring System

Real-Time Temperature Monitoring in EAF Applications

Process Matrix VIPER sensor is a non-contact instrument designed to accurately measure steel melt temperature in real-time. Adapted to monitor radiant emissions through the virtual pipe of a specially designed Comet burner,



VIPER has the potential to reduce processing time, optimize energy consumption, reduce consumables use, and improve safety in EAF applications.



PMC provides industrial process control solutions for the steel industry using intelligent instrumentation. We currently offer laser contouring systems for furnace refractory thickness monitoring, as well as laser-based sensors for particle size and concentration.

Commercial Status: Mature

Contact Information:

www.processmetrix.com

phues@processmetrix.com

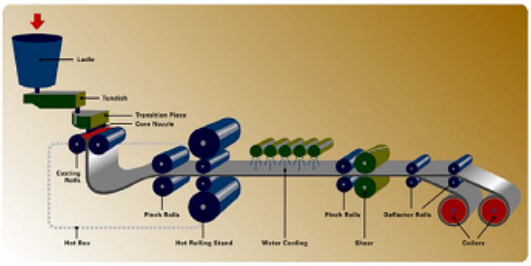
5.2.1 Castrip® Technology

Australia: State-of-the-Art Clean Technologies for Iron and Steelmaking

Castrip® Technology

The Castrip® process is a new technology that has been developed to allow the direct casting of thin strip from liquid steel, in gauges currently ranging from 0.8mm to 2.0mm.

Castrip was developed by BlueScope Steel (formerly BHP) and IHI in the 1990's. In late 1999, Nucor joined the team committing to help commercialise the technology and formed Castrip LLC.



Process flow diagram for the Castrip® process

Benefits

- **Energy** – Potential 80-90% energy savings over conventional slab casting and hot rolling methods.
- **Environment** – More tolerant of high residual elements without loss of quality enabling greater flexibility in ferrous feed sourcing. Potential for higher scrap recycling rates and less dependence on pig iron and HBI.

Commercialization: Emerging

- First commercial Castrip facility constructed in 2002 at Nucor Crawfordsville, Indiana.
- Second Castrip plant to be built at Nucor Yamato, Arkansas. Expect to break ground early 2007.

Contact
Castrip LLC
http://www.castrip.com

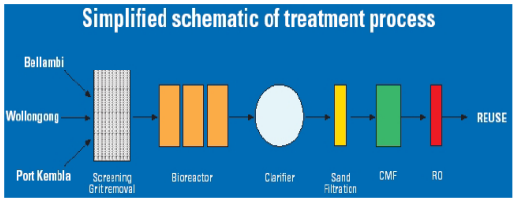
7.1 Reducing Fresh Water Use

Australia: State-of-the-Art Clean Technologies for Iron and Steelmaking

Water saving schemes at BlueScope Port Kembla

Australia is experiencing a drought with a growing population and BlueScope Port Kembla is the largest single user of water in the Sydney area. This is the driving force behind initiatives for reducing the steel works dependence on fresh water.

• Municipal waste water reclamation
– Treatment of sewerage water using micro-filtration and reverse osmosis technology for re-use as industrial water at BlueScope Port Kembla. Sydney Water owns the waste water treatment plant.



• Internal waste water recycling schemes
- Cooling tower blowdown water from the Hot Strip Mill and Slab Casters do not go to the drain, it is treated and re-used for dust collection in Steelmaking.

• Stormwater containment initiatives
- 13M litre synthetic lined water recovery basin in Coke Ovens area collects rainwater, coal stockpile run off water and spent water from Coke quenching for re-use at Gas Processing and Coke quenching.

Benefits

• Environment & community
- Using recycled sewerage water has reduced fresh dam water use on site by 20ML/ day.
- HSM and Caster blowdown water saves Steelmaking 0.5ML/day.
- Total water use is currently 2.3kL/slab tonne. Recycling reduces fresh dam water use to 1.0kL/slab tonne.

Commercialisation: Mature

• Technologies used by BlueScope Steel and Sydney Water are commercially available.

Contacts
Sydney Water
http://www.sydneywater.com.au
BlueScope Steel
http://www.bluescopesteel.com

State-of-the-Art Clean Technologies for Recycling?

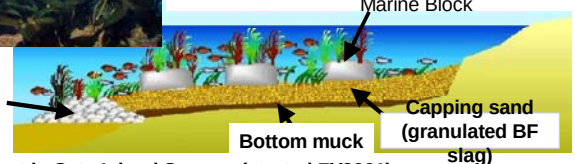
Recycling Activities in the Japanese Iron & Steel Industry

.Japanese Iron & Steel Industry implement ??g recycling activities as a whole. Such activities are development of use technologies taking advantage of properties of slag and promotion of use in society by standardization under JIS, etc. Examples of development of applications for Iron and Steel Slag in new fields are Water/bottom muck purification materials and Marine Block(carbonated steel slag block)

Growth of seaweed (*Ecklonia cava*) on JFE Steel's Marine Blocks



Restoration of lost shallows and seaweed beds



1. Test project in Seto Inland Sea (started FY2001)
2. National Project in Osaka Bay (started FY2004)

Benefits
1. Water/bottom muck purification materials using steel slag and granulated BF slag reduce phosphate concentration, which is cause of red tide and fix hydrogen sulfide, which is cause of blue tide and granulated BF slag prevent generation of hydrogen sulfide
2. Marine Block (carbonated steel slag block) help? to grow seaweed which improve sea surroundings

Contact
1.?FE Steel Corporation
http//www.jfe-steel.co.jp/
2. JISF?apan?ron?and Steel Federation?http//www.jisf.or.jp

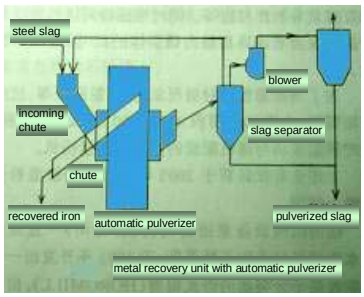
7.2 Slag Recycling

China: State-of-the-Art Clean Technologies for energy saving

Slag pulverization process

➢Steel slag pulverization is a process during which water will be sprayed when the slag temperature is at 600? 800? . Water spray will produce hot steam which reacts with free CaO and free MgO. Consequently the slag will be pulverized due to volume expansion, thus to make steel be naturally separated from slag.

➢Steel slag generated in 2004 is 38,190,000 t in China. However the utilization ratio is only 10%. By using the process mentioned above slag can be well separated from iron with good stability. So this by-product can be widely used in various building industry.



metallic iron recovered with automatic slag pulverizer

Benefits

- **Economical result** –around 3,800,000 t/a scrap steel can be totally recovered from the yearly generated slag. This will bring a revenue of 3.8 billion yuan per year based on 1000 yuan/t scrap steel.
- If using 30,000,000 slag to produce the mixing material for slag-made cement, all slag can be utilized. The average sales price of pulverized slag is 180 yuan/t which can create production value of 5.4 billion yuan and profit of 2.1 billion yuan based on a profit rate of 70 yuan/t.
- **Environment** –slag will be totally utilized as a substitute of cement in building industry thus can minimize CO_2 emission during cement production.
- **Land occupation:** by slag reutilization the land area occupied by piled slag can be minimized.

Commercialization: Emerging

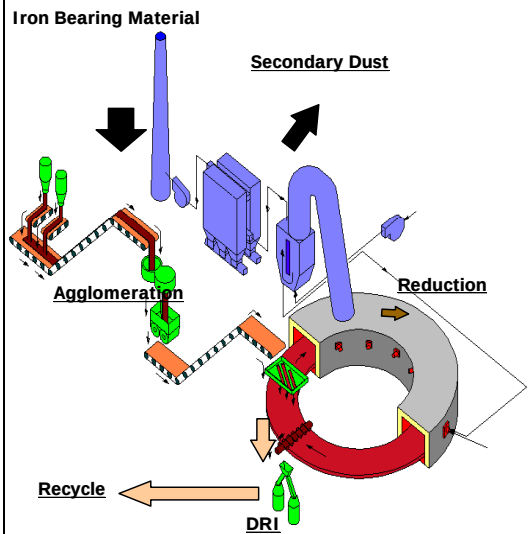
- This technology was developed by the Central Engineering Institute of Building Industry under MCC in 80s of 20 centaury.
- It has been proved a good result after being utilized in Shanghai No. 5 Steel, Beitai Steel, Hunan Lianyuan Steel, etc. over the past 10 years.

Contact

7.3 Rotary Hearth Furnace Dust Recycling Technology

JAPAN: State-of-the-Art Clean Technologies for Ironmaking/By-products Utilization

Rotary Hearth Furnace



Advantages of Dust Recycling

Benefits

1. Decreasing of Waste Emission

?**Saving of waste disposal cost**

?**Extending landfill life**

2. Recovery of Unused Resources

?**Recycling Iron, Nickel, Zinc etc in Waste**

?**Utilizing carbon in waste for reduction**

3. Improvement in Ironmaking Operation

?**Increase in productivity**

?**Decrease in coke ratio by charging DRI to BF**

Commercialization: Emerging

Contact
Shinjiro Uchida, Nippon Steel Engineering
http://www.nsc-eng.co.jp

7.4 Activated Carbon Absorption

Republic of Korea: State-of-the-Art Clean Technologies for Coke making Wastewater Treatment

Activated Carbon Absorption

Description :

High pollutants removal efficency of Activated carbon adsorption system has been proved in many cases. Activated carbon adsorption system used not ony to eliminate the typical yellow brown color of coke wastewater which causes some complaints from stakehoders but also to reduce COD of secondary wastewater treatment plant.



Benefits

- **Colorless of Coke wastewater**
- **Significant reduction of COD**
  - Below 5 mg/?
- **Heavy metals removal**
  - Characteristics of activated carbon adsorption

Commercialization: Mature

- First commercial facility in Kwangyang secondary wastewater treatment plant operated since 1988.
- Installation for Coke wastewater plant in 2002

Contact
Mr. Youngdo Jang
Dept. Environmet& Energy, POSCO
T +82-54-220-5773
ydjang@posco.co.kr

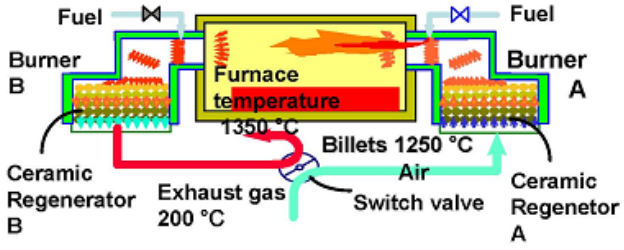
8.11 Regenerative Burner

Japan: State-of-the-Art Clean Technologies for Ironmaking

Application of Regenerative Burner to Iron and Steel Industry

Regenerative Burner is a high efficient heat recovery system by recovering waste heat of the furnace exhaust gas to heat-up combustion air at the furnace site by installing heat recovering regenerator.

The key technology of Regenerative Burner is to set a pair of burner with regenerator at each burner. During combustion, one side of a burner combust fuel where another side of burner accumulate heat of exhaust gas into heat recovering regenerator. Then combusting burner switch and burner accumulated heat of exhaust gas combust fuel using high temperature combustion air which takes heat out of heat recovering regenerator, where the other side of burner accumulate heat of exhaust gas into another heat recovering regenerator, securing stable combustion and high-efficient combustion as well as low NOx.



Benefits

- **Energy** – Approximately 20to 50%of energy reduction is possible. The reduction range differ according to the types of furnace and types and condition of fuel
- **Environment** –Maximum of 50% of NOx reduction is possible with high temperature combustion. The reduction range differ according to the types of furnace and types and condition of fuel
- **Reliability** – Excellent operational reliability. Over 540 furnaces in Japanese various industry has already introduced regenerative burner system.

Commercialization: Mature

- First commercial facility constructed in 1996.

Contact

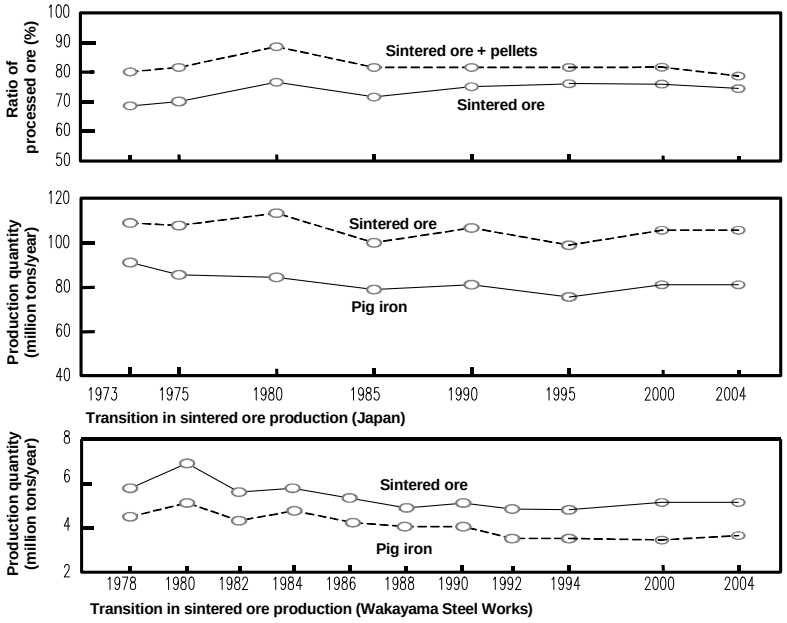
1.JFE Steel Corporation
http//www.jfe-steel.co.jp/
2.JISF(Japan Iron and Steel federation)
http//www.jisf.or.jp

Appendix 2 (Extended Technology Information Provided)

1.1 Sintering - Background

Japan - Best Available Technologies for Sintering

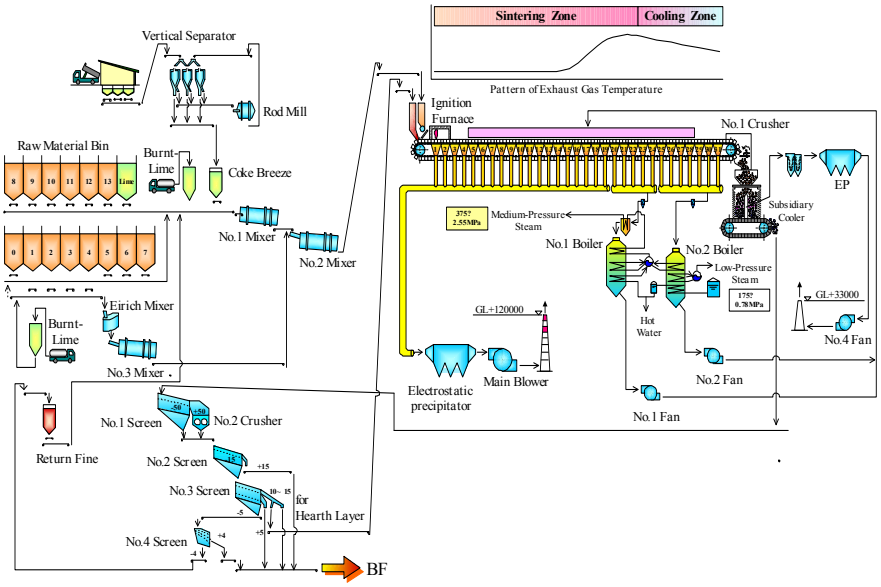
1. Transition in Sintered Ore Production



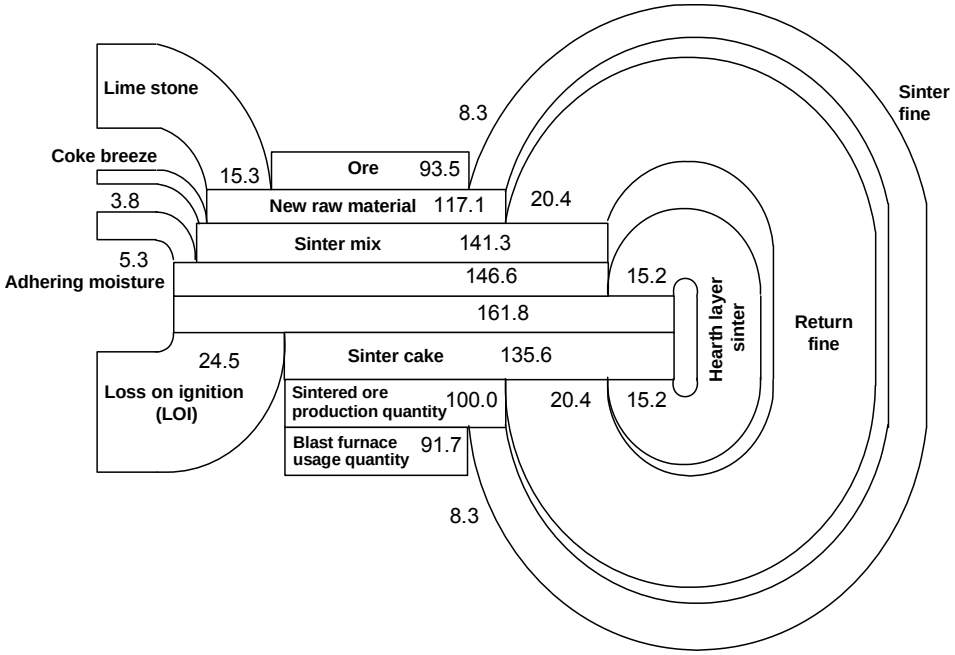
Japan - Best Available Technologies for Sintering

2. Sintering Process Equipment Flow

(No. 4 Sintering Plant , Wakayama Steel Works, Sumitomo Metal)



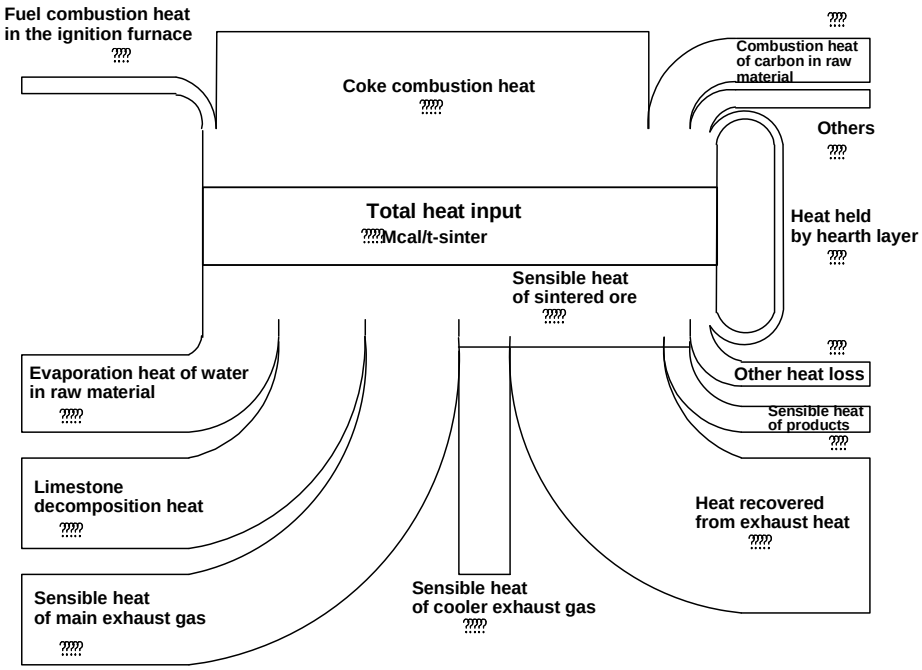
• Balance of materials in the sintering process



No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries

Japan - Best Available Technologies for Sintering

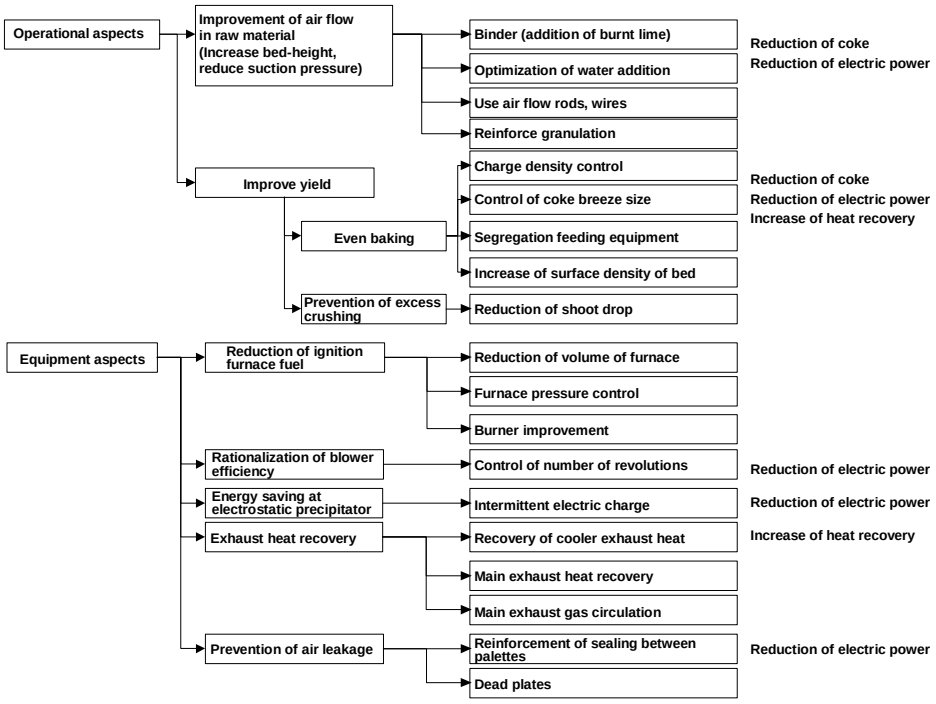
• Balance of heat in the sintering process



No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries

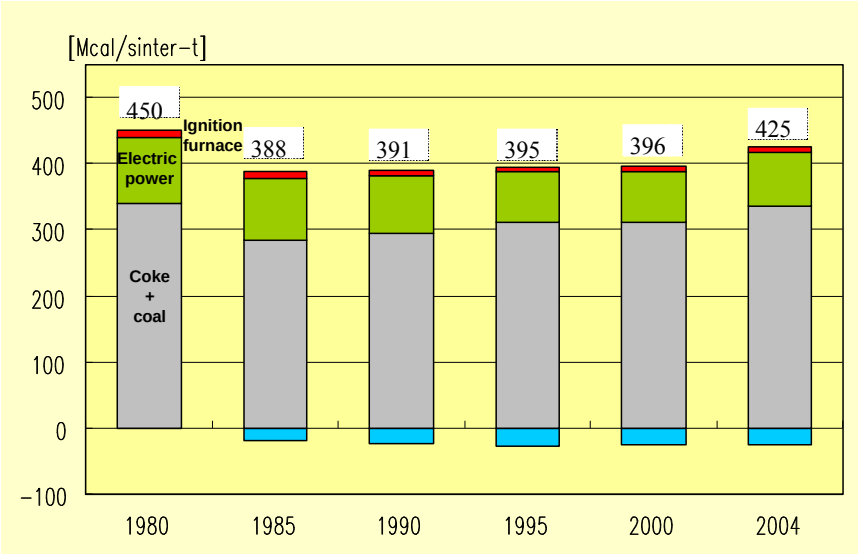
Japan - Best Available Technologies for Sintering

Energy saving in the sintering process

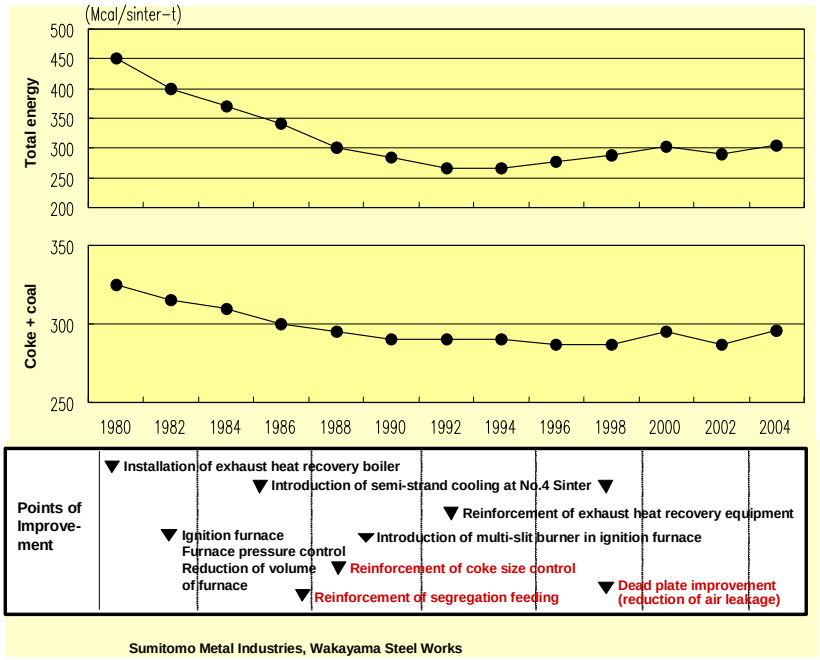


Japan - Best Available Technologies for Sintering

Total Iron and Steel Industry in Japan



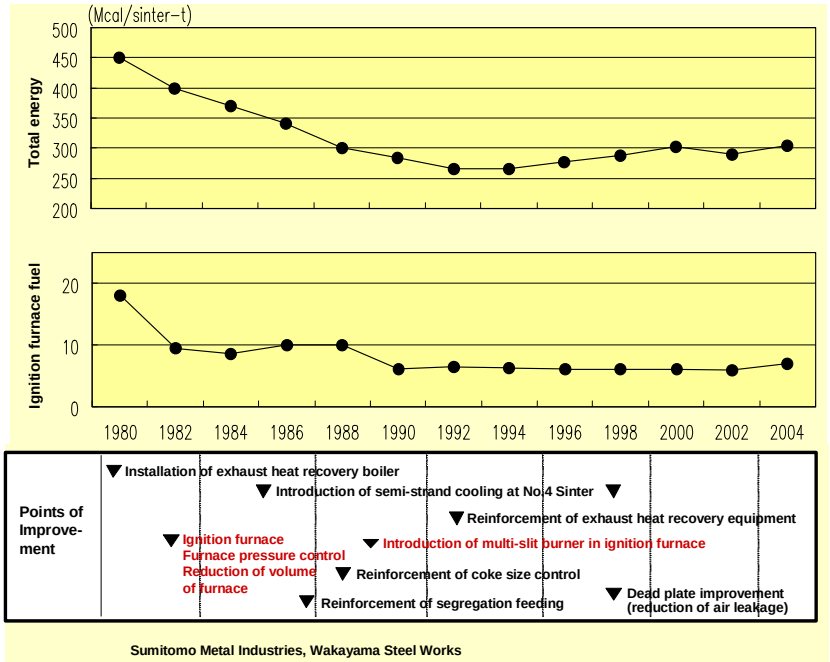
3. Transition of Energy in the Sintering Process



Sumitomo Metal Industries, Wakayama Steel Works

Japan - Best Available Technologies for Sintering

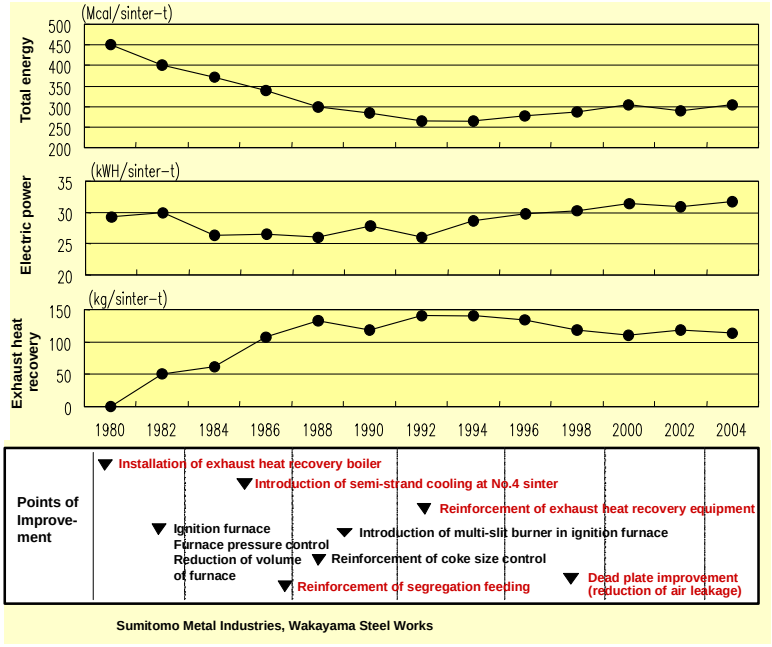
- ***Transition of energy saving at Wakayama Sintering Plant***



Sumitomo Metal Industries, Wakayama Steel Works

Japan - Best Available Technologies for Sintering

- ***Transition of energy saving at Wakayama Sintering***



Sumitomo Metal Industries, Wakayama Steel Works

1.1.1 Sinter Plant Heat Recovery

India Best Available Technologies for Sintering

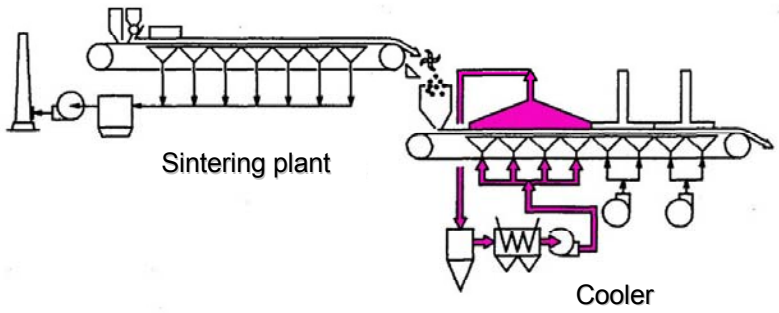
Energy Saving Equipment and Practices

- Recover energy from sinter coolers and exhaust gases

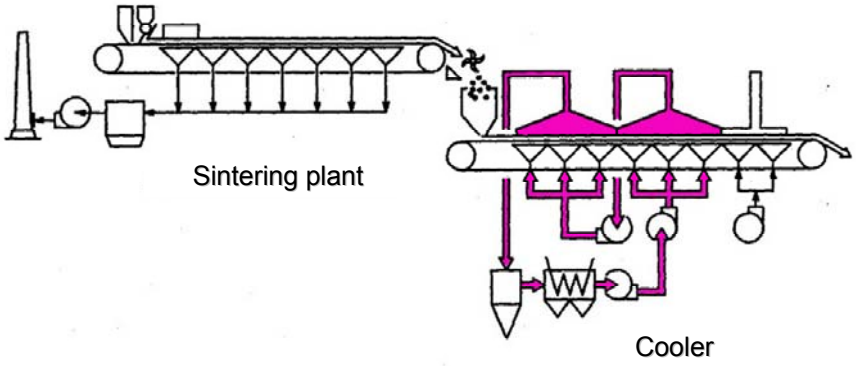
  -- The facility is available in some of the steel works. Retrofitting of the system could not be done due to space and logistic problems. Can be thought of if suitable technology / design supplier is available.

1. Example for Sintering Exhaust Heat Recovery Equipment

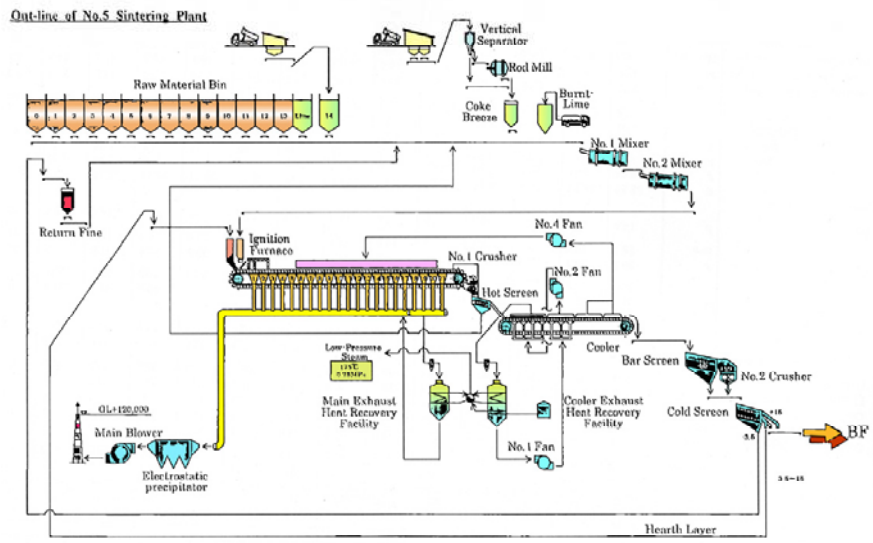
- *Recovery of exhaust heat from cooler*



- *Recovery of exhaust heat from cooler - 2-pass*



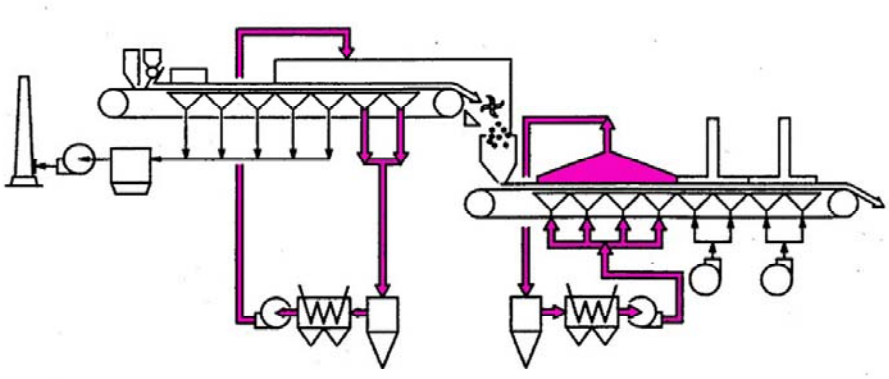
- ***Exhaust heat recovery flow at Wakayama No. 5 Sintering Plant***



Flow of the exhaust heat recovery from the sintering process
(No. 5 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

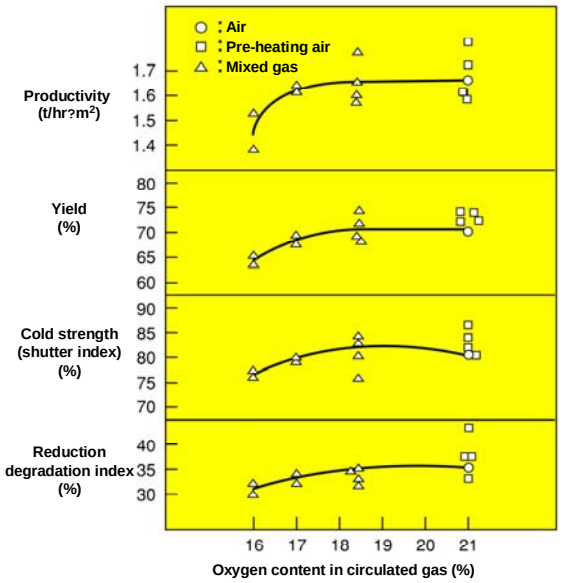
Japan - Best Available Technologies for Sintering

- ***Main exhaust gas circulation + recovery of exhaust heat from cooler***



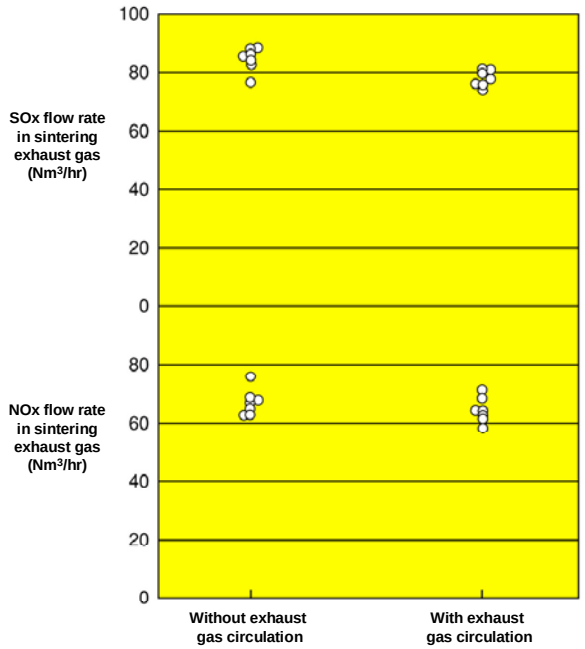
2. Influence of Main Exhaust Gas Circulation on Sintering Operation

- *Influence from oxygen content in circulated gas*

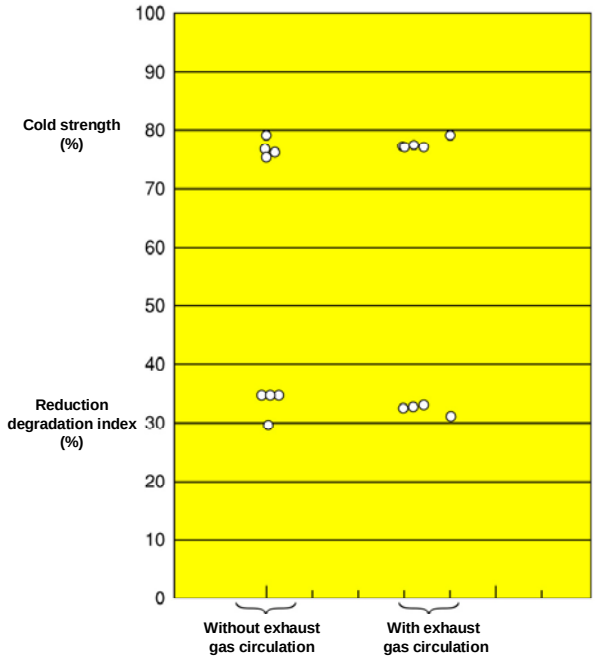


Japan - Best Available Technologies for Sintering

- *Influence of main exhaust gas circulation on exhaust gas*



- ***Influence of main exhaust gas circulation on the quality of sintered ore***

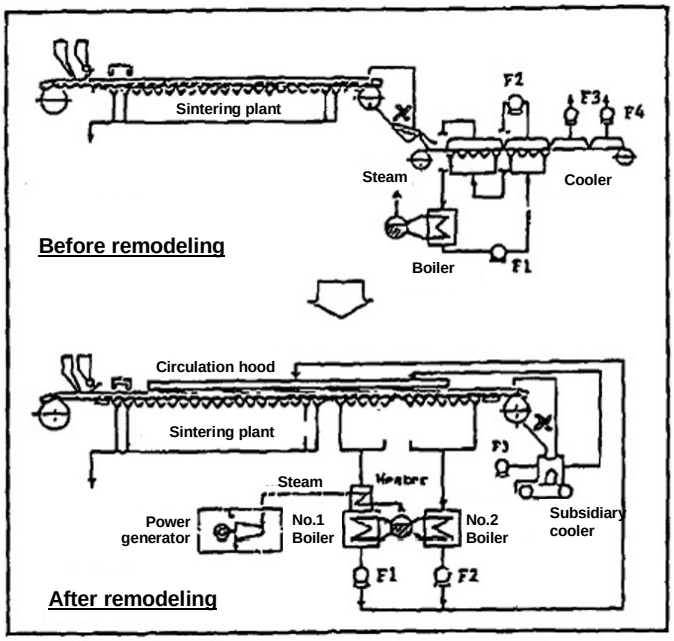


Japan - Best Available Technologies for Sintering

- ***Results from the trial operation with main exhaust gas circulation***

Item	Test operation result
Main exhaust gas circulation ratio	20-25%
Quantity of recovered steam	110 – 120 kg / sinter-t
Productivity	Same as without circulation
TI	Same as above
RDI	Same as above
Coke	3 – 4% reduction
Total SOx quantity	3 – 10% reduction
Total NOx quantity	3 – 8% reduction
Dust (at EP inlet)	About 30% reduction
Oxygen content in circulated gas	18 – 20%
Circulated gas temperature	About 200 ℃

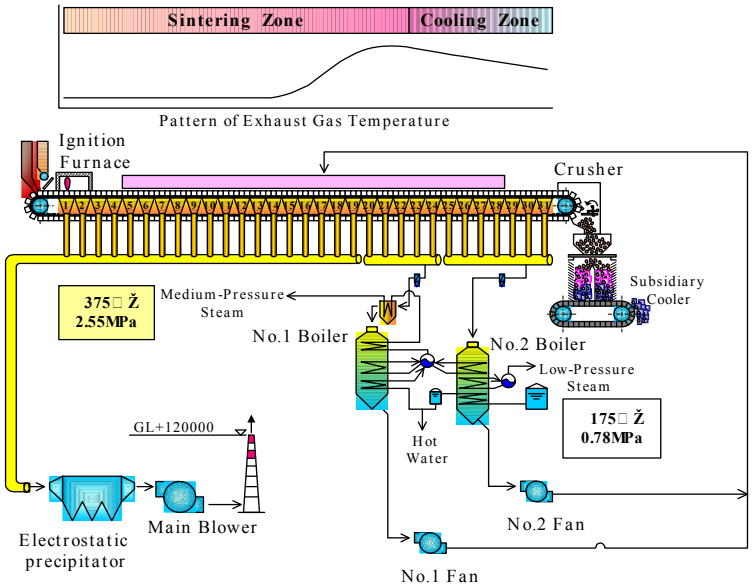
- ***Exhaust heat recovery flow before and after the introduction of semi-strand cooling***



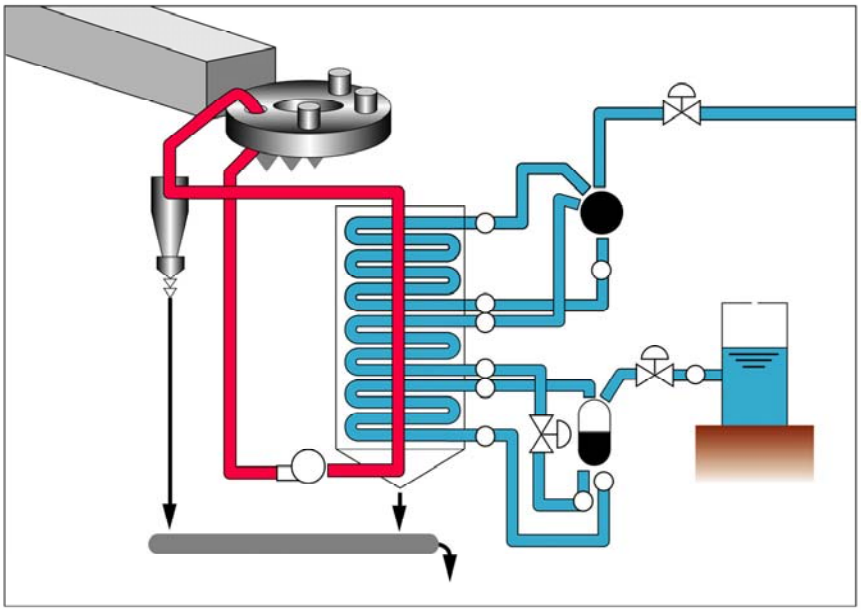
Exhaust heat recovery flow before and after the introduction of semi-strand cooling (No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

Japan - Best Available Technologies for Sintering

- ***Exhaust heat recovery flow at Wakayama No. 4 Sintering Plant***



3. Sintering Cooler Exhaust Heat Recovery at Taiyuan Steel Works



- ***Meaning of model project at Taiyuan Steel Works***

Before	**1. Heat emission from cooler**	**Heat release using cooling fans**
	2. Dust at cooler	**Diffused with cooling fans**
Changes	**1. Heat emission from cooler**	**Recover exhaust heat and turn it into steam in a boiler** **Recovered steam quantity: 15 t / h (corresponds to 12,000 KL/year of crude oil)** **→ Reduction of fossil fuel used for production (corresponding to the quantity of recovered steam)** **→ Reduction of manufacturing costs** **Reduction of CO_2 and SO_2 generation (with the effect of preventing global warming)**
	2. Dust at cooler	**80% of the diffused dust is recovered in dust collectors** **Effective for environmental protection**

1.1.2 District Heating Using Waste Heat

Korea - Best Available Technologies for Sintering

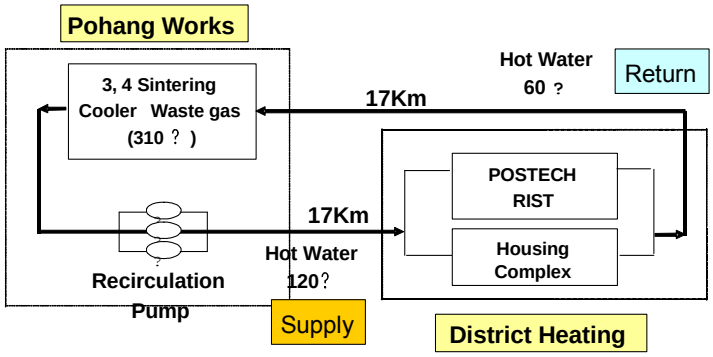
District Heating with Using Waste Heat

- ❑ Construction Period : 2000. 9 ~ 2001.10
- ❑ Investment : 22.3 mil $
- ❑ Heat Source : (PW) 3,4 Sintering Cooler Waste Heat
- ❑ District : POSTECH, RIST, Housing Complex
- ❑ Total Length of Pipe : 34 Km
- ❑ Effect : District Heating of 5,000 Houses , 19 kilo TOE/year



Republic of Korea: State-of-the-Art Clean Technologies

District Heating Using Waste Heat



❑ Construction Period : 2000. 9 ~ 2001.10
❑ Investment : 22.3 mil $
❑ Heat Source : (PW) 3,4 Sintering Cooler Waste Heat
❑ District : POSTECH, RIST, Housing Complex
❑ Total Length of Pipe : 34 Km
❑ Effect : District Heating of 5,000 Houses , 19 kilo TOE/year

District heating using waste heat in steel industry is a good model not only to save the energy, but also to share our resources with district residents. The total length of 34km is a long distance to transfer heat efficiently. In spite of this long distance, POSCO decided to construct a district heating system. Using waste heat, fossil energies, such as LPG/LNG, are substituted.

1.1.3 Dust Emission Control

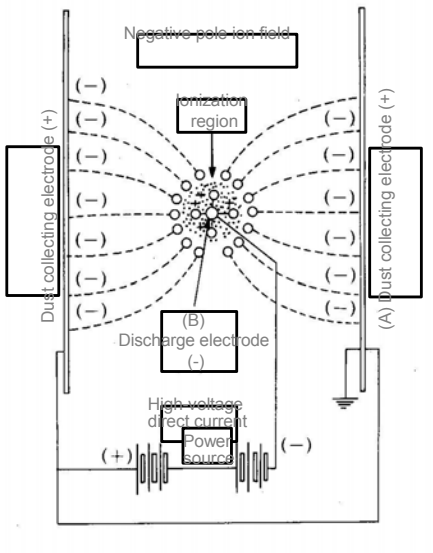
Japan - Best Available Technologies for Sintering

1. Sintering Plant - Exhaust Gas Precipitator

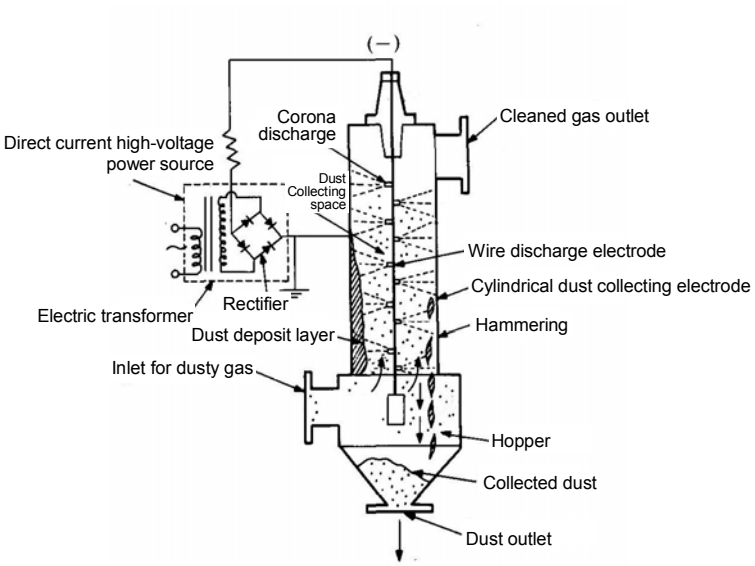
	Dust collecting capacity	Maintenance	Response to oil content	Cost of operation (Pressure drop)	Cost of equipment
Cyclone	Small	Easy	-	Medium	Low
Bag filter	Large	Difficult	Difficult	High	Medium
Electrostatic precipitator	Medium	Medium	Medium	Low	High

Japan - Best Available Technologies for Sintering

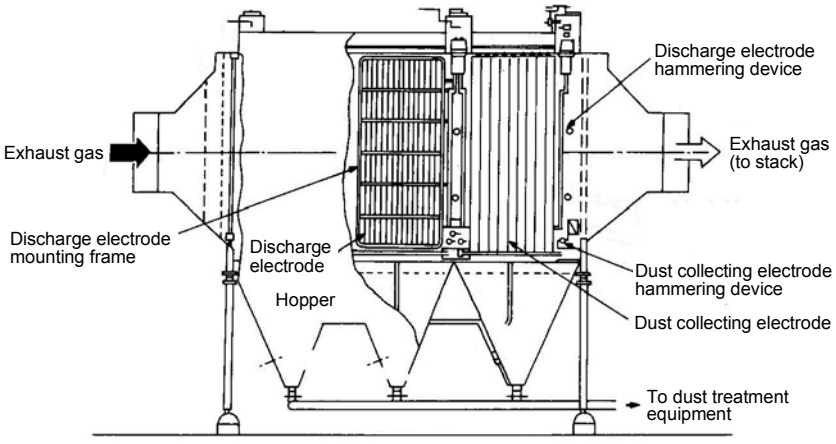
- **Principle of Electrostatic Precipitators (Flat Plate Type)**



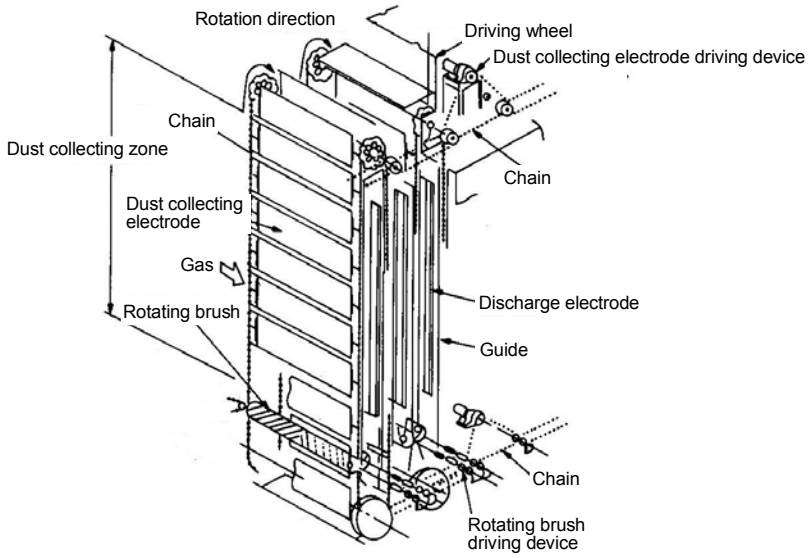
Principle of Electrostatic Precipitators (Cylindrical Type)



Electrostatic Precipitator Equipment (Dry Flat Plate Type)

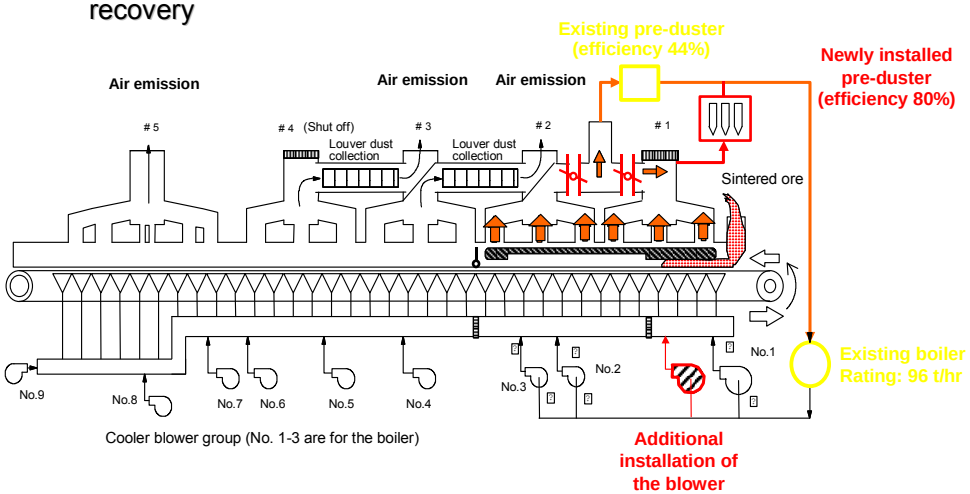


• Mobile Electrode Electrostatic Precipitator

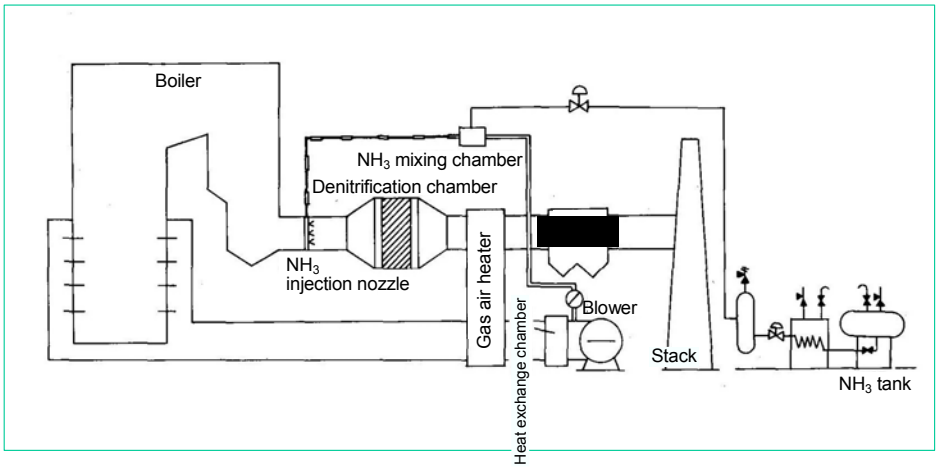


2. Sinter Cooler - Dust Control

- Production increase leads to increase of dust generation from the sinter cooler → increase of environmental emission
- Measure: forced dust generation in the waste heat collecting zone and collection by pre-duster
- Effect: control of dust emissions, increased quantity of steam recovery



3. Sintering Exhaust Gas - Denitrification Equipment

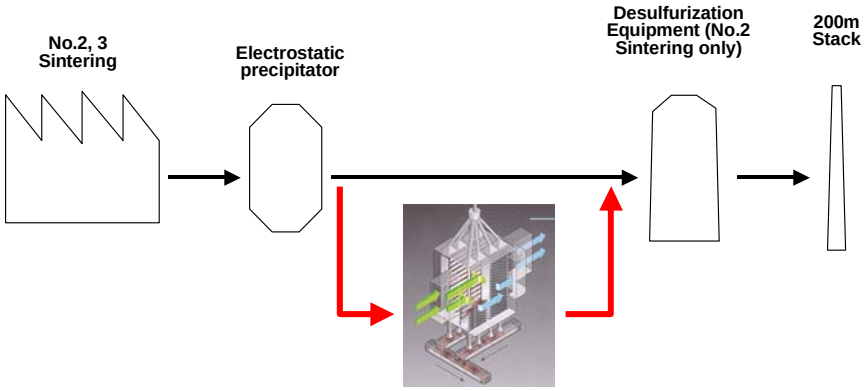


4. Comparison of Treatment Methods for Sintering Plant Exhaust Gas

	Activated coke absorption method	Dielectric exhaust gas purifying equipment	Mobile electrode electrostatic precipitator	Catalyst method
Dioxin in particulate form	Collect and decompose	Collect	Collect	Difficult
Dioxin in gaseous form	Absorb and decompose	Collect (uncertain)	Difficult	Decompose (require NH_3)
Dust	Collect	Collect	Collect	NON
SOx	Absorb*	Absorb*	NON	NON
NOx	Decompose (require NH_3)	NON	NON	Decompose (require NH_3)

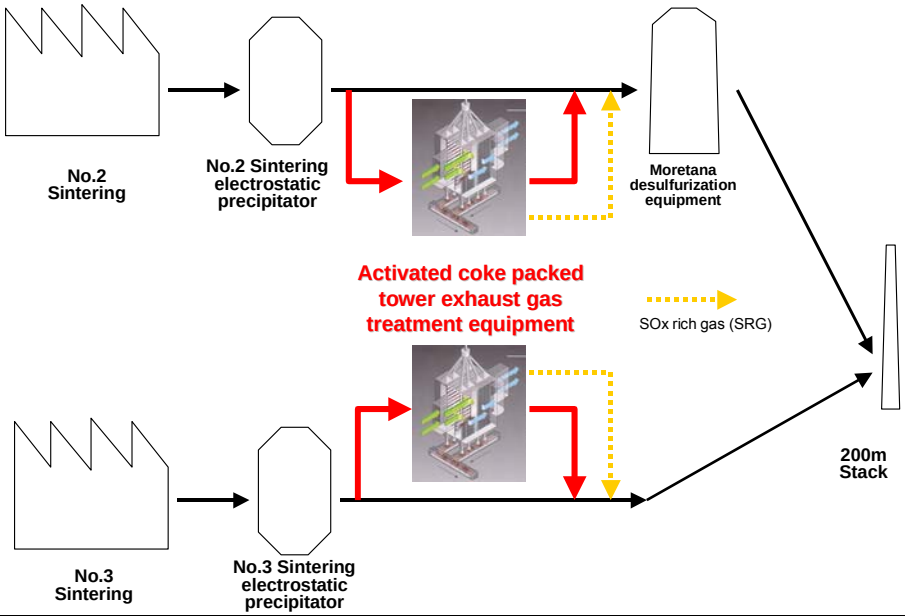
* require De-SOx equipment

5. Treatment Process for Sintering Exhaust Gas at Kashima Steel Works



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- **Sintering Exhaust Gas Treatment Flow (before improvement)**



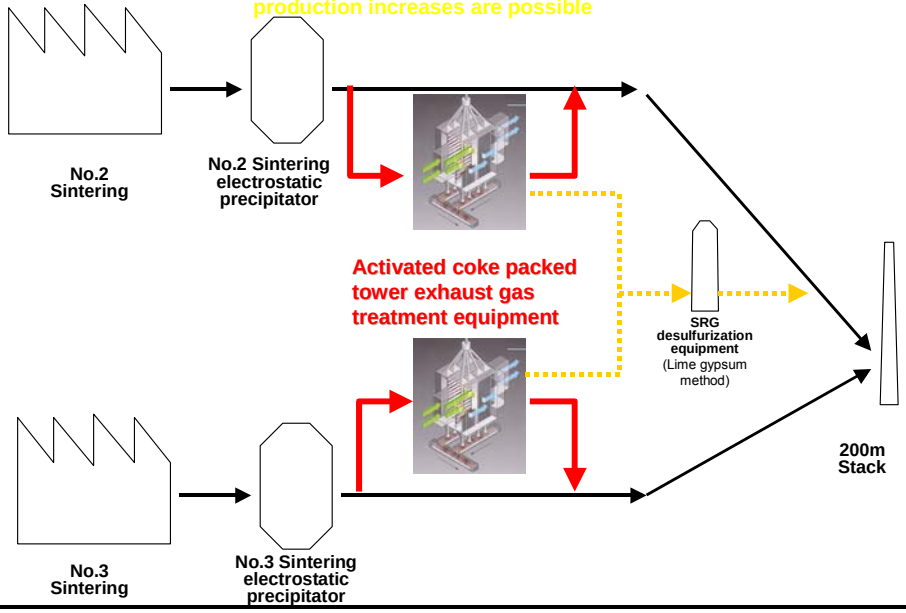
Japan - Best Available Technologies for Sintering

- **Sintering Exhaust Gas Treatment Flow (after improvement)**

Points of improvement: Higher desulfurization capacity → Reduction of total SOx quantities, usage of material with high sulfur contents possible

? ? ? ? ? ?

Reduction of main exhaust line pressure drops → response to production increases are possible



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Dust Emissions Control

Dedusting System for Conventional Sintermaking

A conventional sinter plant dedusting system achieves over 98% efficiency, reducing the dust load in the off-gas of a typical plant from 3,000 mg/m^3 to about 50 mg/m^3.

Off-gas Flow Path of Sinter Plant

- Fans or turboblowers suction the sinter waste gas along sinter strands. The exhaust flow rate ranges from 1,500 - 2,500 m^3/t$_{sinter}$ with gas temperatures around 70-105°C.
- Windboxes take the waste gas to collector mains.
- Collector mains are connected via dust catchers with the inlet mains to the Electrostatic Precipitators (ESPs).

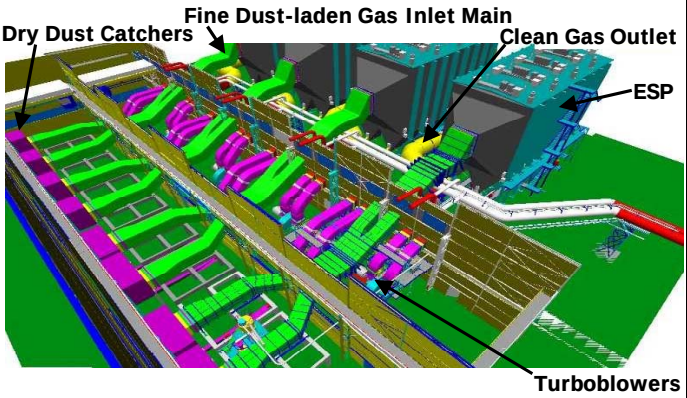


Illustration of Sinter Plant Waste Gas Treatment Unit

Dedusting Process Overview

- **Large particulates/Coarse dusts** arise from the feed sinter mixture before evaporation of water. The course dusts are removed in dry dust catchers installed at the end of collector mains and recycled through the sinter process.
- **Fine dust** arises from the sinter process after water evaporation is complete. The fine dust can be separated by ESPs or bag filters with high dedusting efficiency.

Fine Dust Removal by Electrostatic Precipitator

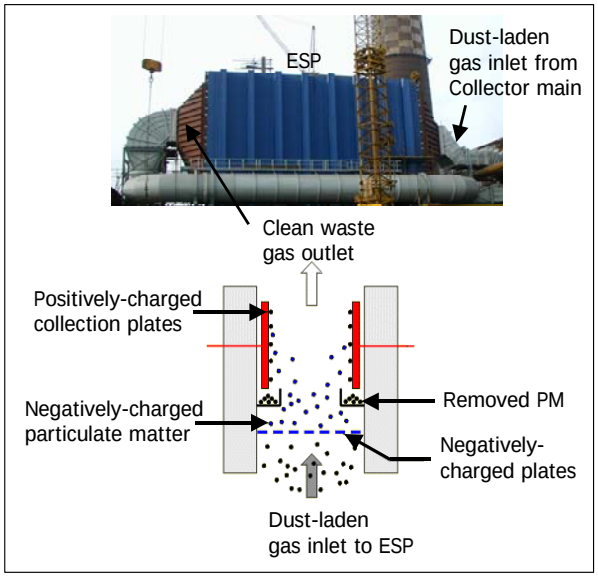
ESP removal of fine dust, which consists of iron oxides, alkali chlorides, heavy metal oxides, etc., may reduce PM emission levels at sinter plants to about 50 – 150 mg/m^3 depending on actual Specific Dust Resistivity (SDR) and/or sinter basicity.

Collector mains, which are connected to the dust catchers, route waste gas to the ESP. Dust-laden waste gas is sent into the ESP through pipes having negatively charged plates which give the PM in the waste gas stream a negative charge. The stream is then routed past positively charged plates, which attract and collect the negatively-charged particulate matter.

Typical dedusting systems are configured with multiple ESPs arranged in series.

ESP details

- ESPs can be installed at new and existing plants
- ESPs will cause specific energy consumption for sintermaking to increase about 0.002 – 0.003 GJ/t $_{\text{sinter}}$
- Attention must be paid to the hydrocarbon level in the raw waste gas (e.g. by mill scale recycling control) to avoid the risk of fire



Flow diagram and photo of ESP

United States - Best Available Technologies for Sintering

Fine Dust Treatment and Recycling

Fine dust from sections 1-3 of an ESP can be recycled through the sinter blending yard. In the first three sections a PIACS classic voltage source (in 400V/50Hz, out 90,000V) is used.

In the last section of an ESP, dust with the finest particles and the highest alkali chloride content must be treated or disposed in landfill. A special pulse energization system COROMAX III is used for the last section (in 400V/50Hz, out 60,000V) for dust with high resistivity.

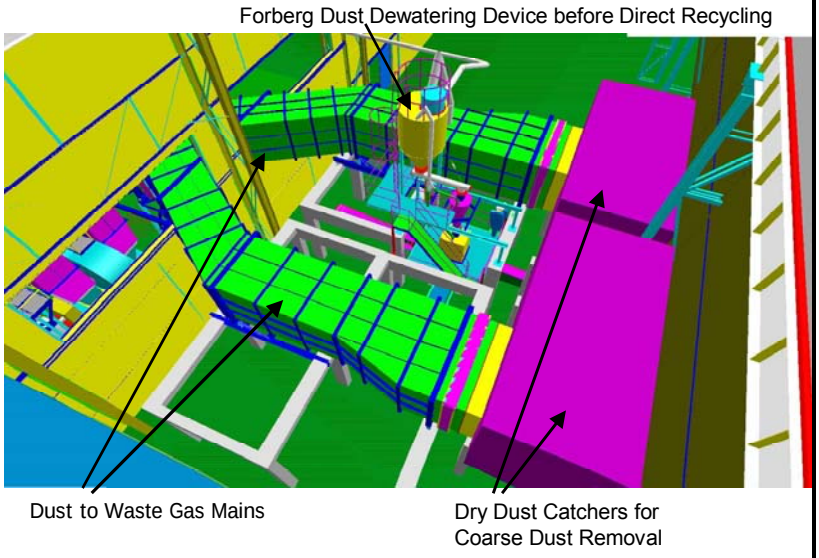
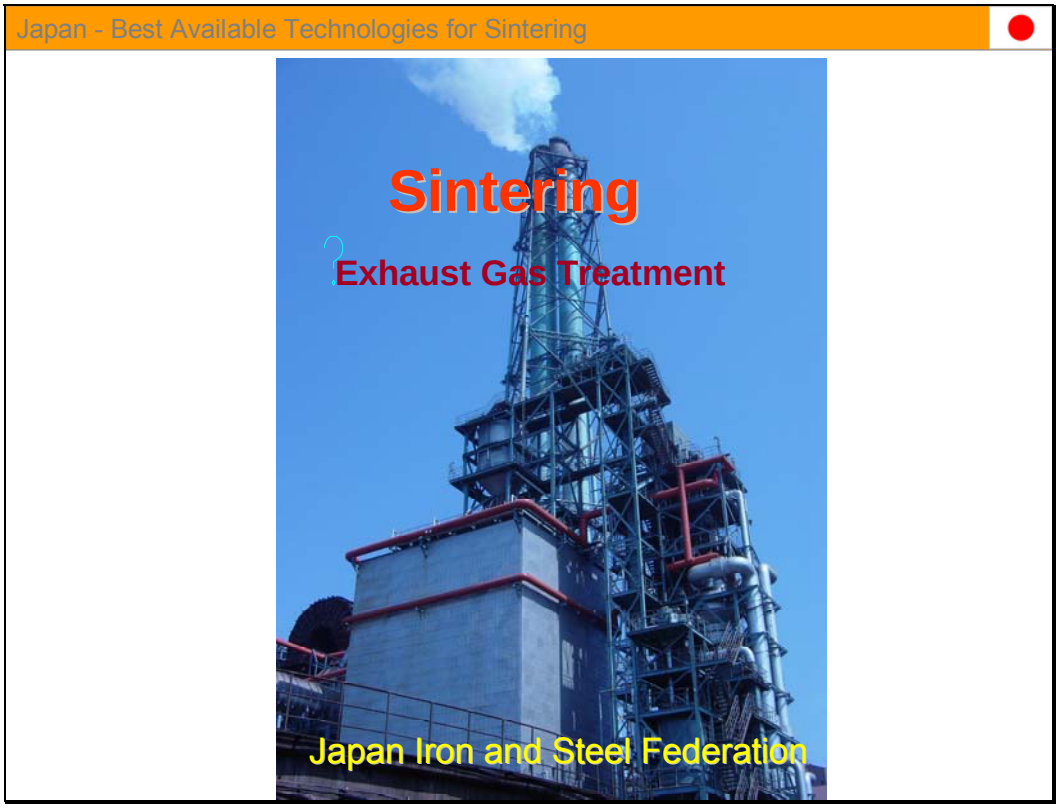


Illustration of Forberg room arrangement for direct recycling

1.1.4 Exhaust Gas Treatment through Denitrification, Desulfurization, and Activated Coke Packed Bed Absorption



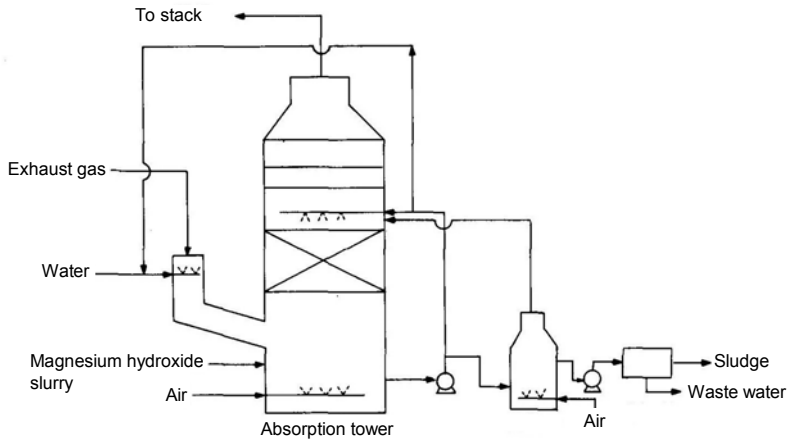


1. Sintering Exhaust Gas - Desulfurization Equipment

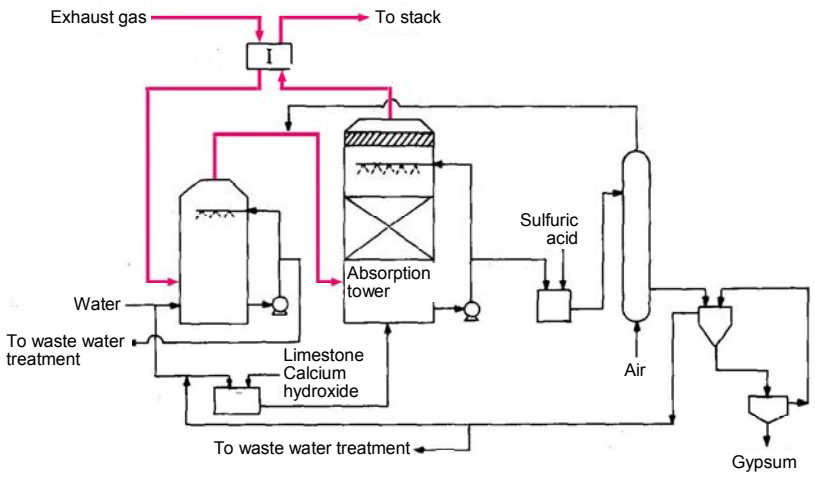
	Scale of equipment	Product	Cost of operation (Cost for agents)	Characteristics
Soda method	Small	Na_2SO_4	High	Suitable for small-scale equipment, since the cost for the agent is high
Magnesium hydroxide method	Medium	$MgSO_4$	Medium	-
Lime gypsum method	Large	Gypsum ($CaSO_4$)	Low	Suitable for large-scale equipment. By-products can be utilized.

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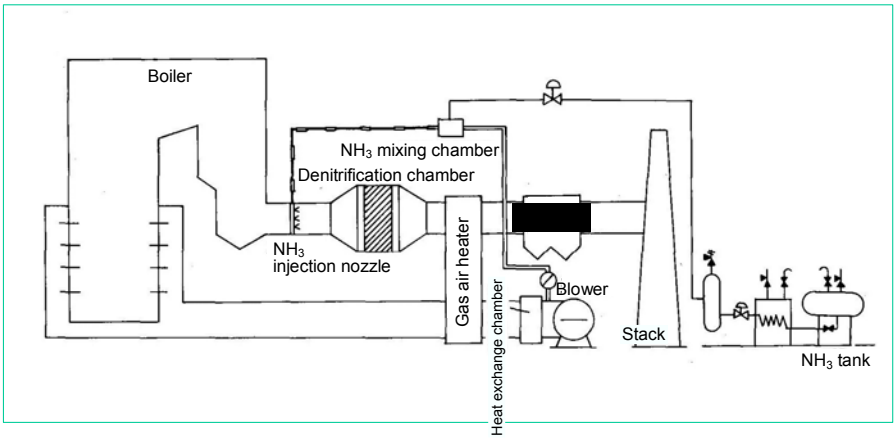
- **Magnesium Hydroxide Slurry Absorption Method**



- **Lime Slurry Absorption Method**



2. Sintering Exhaust Gas - Denitrification Equipment



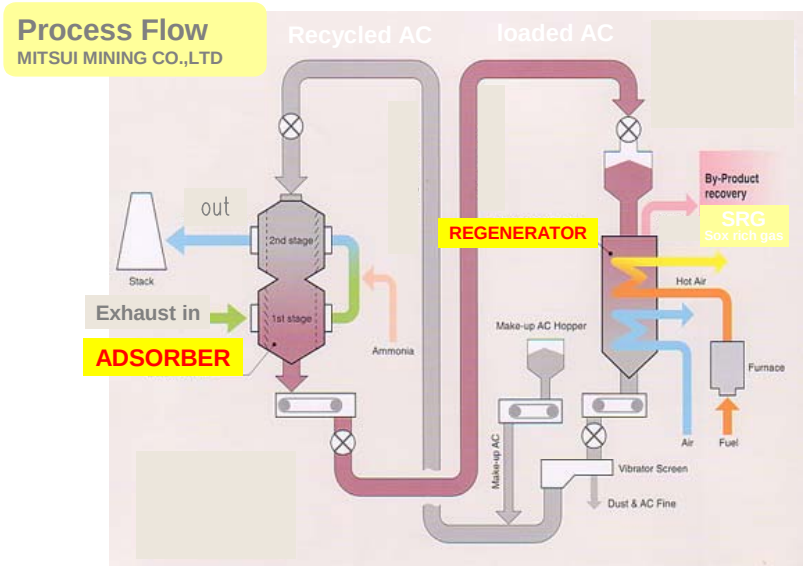
3. Comparison of Treatment Methods for Sintering Plant Exhaust Gas

	Activated coke absorption method	Dielectric exhaust gas purifying equipment	Mobile electrode electrostatic precipitator	Catalyst method
Dioxin in particulate form	Collect and decompose	Collect	Collect	Difficult
Dioxin in gaseous form	Absorb and decompose	Collect (uncertain)	Difficult	Decompose (require NH_3)
Dust	Collect	Collect	Collect	NON
SOx	Absorb*	Absorb*	NON	NON
NOx	Decompose (require NH_3)	NON	NON	Decompose (require NH_3)

* require De-SOx equipment

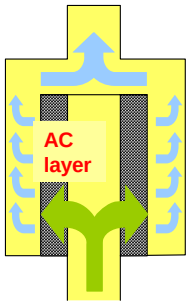
4. Activated Coke Packed Bed Absorption Method

System to eliminate SOx, NOx and dioxin

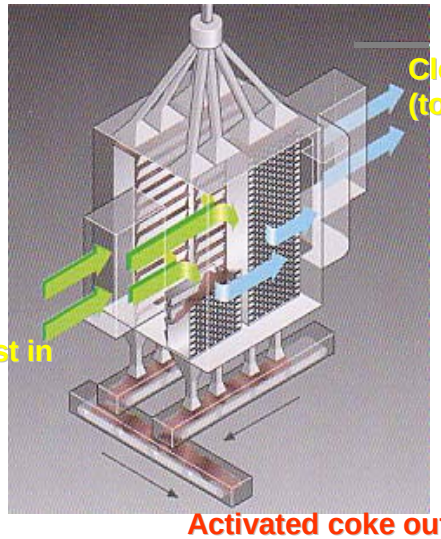


• Absorption of SOx, NOx and Dioxin

Cross section



Activated coke in



Cleaned exhaust out
(to stack)

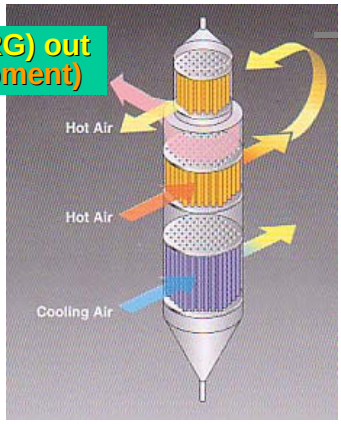
Exhaust in

Activated coke out
(to regenerator)

• Activated Coke Regeneration

Loaded AC in

SOx rich gas (SRG) out
(to De SOx equipment)



Regenerated AC Out
(to Absorber)

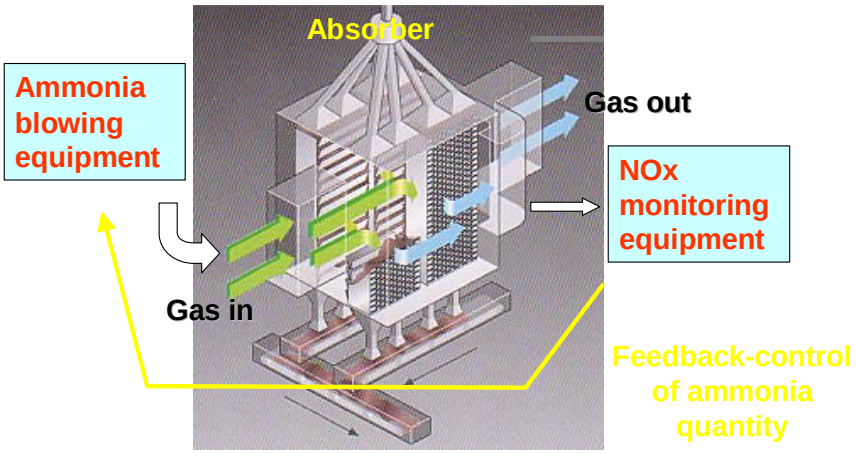
Regeneration
(SOx rich gas)
$2SO_3 + C \rightarrow 2SO_2 + CO_2$
$H_2SO_4 \rightarrow H_2O + SO_3$

Dioxins Decomposition
About 400°C
under no-oxygen

Denitrification Method in Activated Coke absorption

- NOx Decomposition

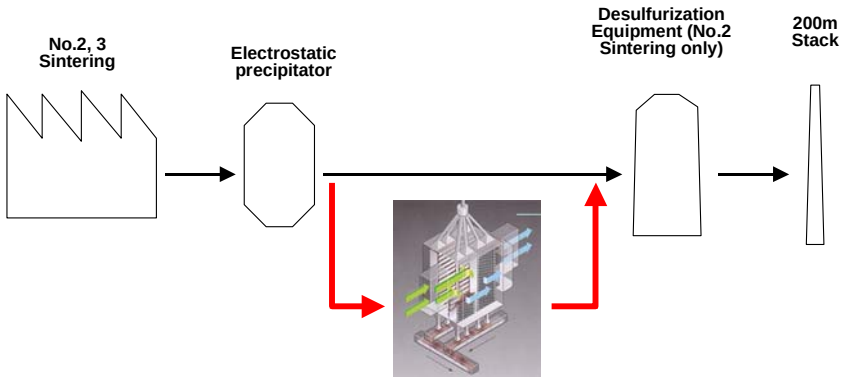
$$4NO+4NH_3 \rightarrow 4N_2+6H_2O+(2x-3)O_2$$



Effect of the Activated Coke absorption Method

	Results
DXNs (ng-TEQ/m^3N)	< 0.1
Dust (mg/m^3N)	< 10
SOx (%?absorbing ratio)	6.5 <
NOx (%?decomposing ratio)	-

5. Treatment Process for Sintering Exhaust Gas at Kashima Steel Works

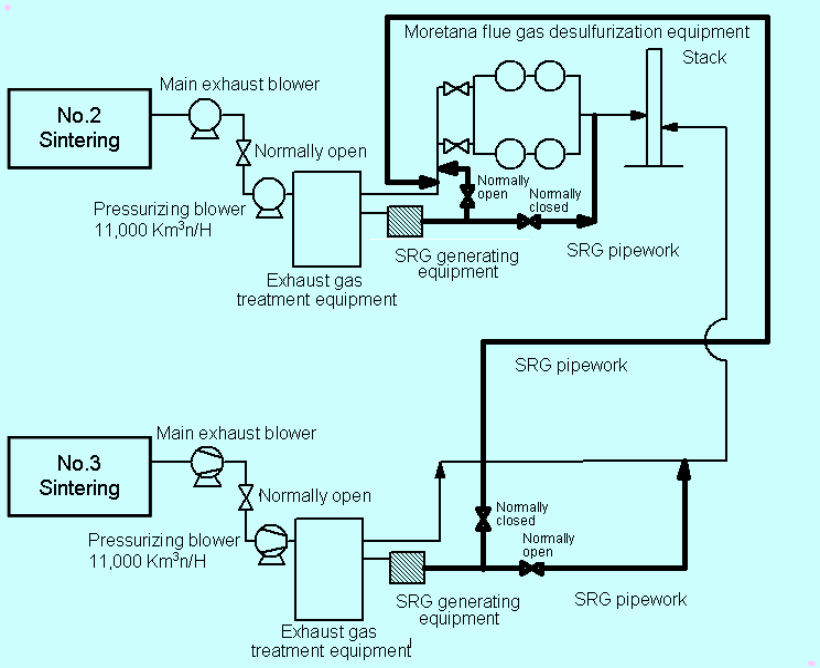


Activated coke absorption tower

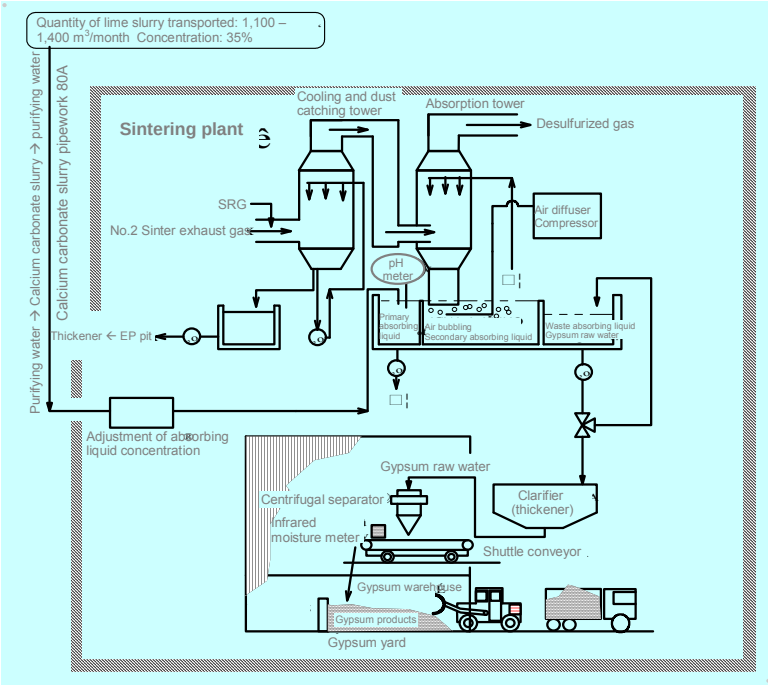
- **Activated Coke absorption Equipment (No.2 Sintering Plant)**



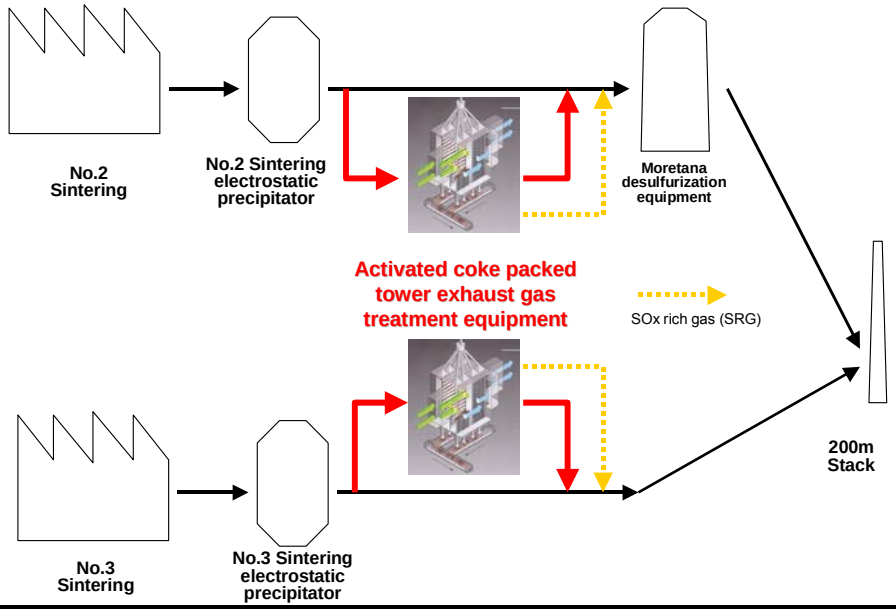
• Desulfurization Equipment Flow Chart



• Moretana Desulfurization Equipment Flow Chart



Sintering Exhaust Gas Treatment Flow (before improvement)



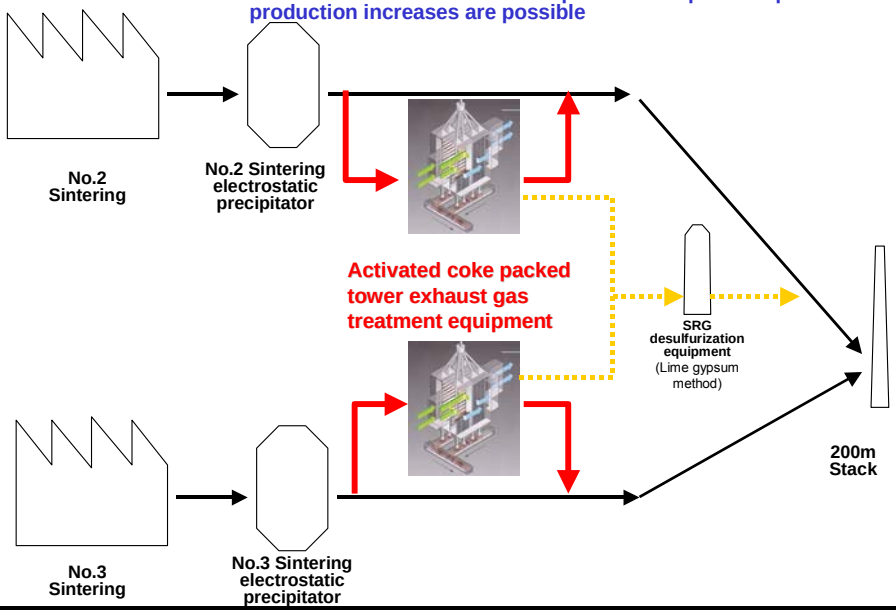
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Desulfurization Equipment for Highly Concentrated SOx Gas (SRG)

- Lime gypsum method
- Magnesium hydroxide method
- Soda method

Sintering Exhaust Gas Treatment Flow (after improvement)

Points of improvement: Higher desulfurization capacity → Reduction of total SOx quantities, usage of material with high sulfur contents possible
Reduction of main exhaust line pressure drops → response to production increases are possible



6. Examples for Limits from Regulations and Agreements and Actual Results

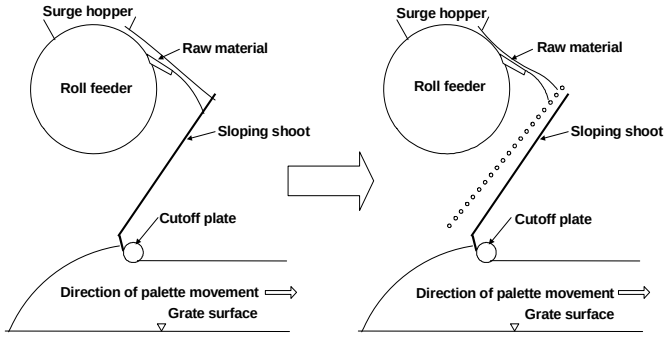
		Limit from Laws and Regulations	Limit from Agreements with Government	Actual Values
SOx	Concentration (ppm)			< 220
	Overall quantity(m^3N/hr)	< 644	< 865	< 420
NOx	Concentration (ppm)	< 260		< 230
	Overall quantity(m^3N/hr)		< 1264	< 590
Dust (mg/m^3N)		< 150	< 60	< 40
DXNs ($ng\text{-}TEQ/m^3N$)		< 1.0		< 0.1

1.1.7 Improvement in Feeding Equipment

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Example for Energy Saving Improvement

- ***Outline of improvements in feeding equipment***



Outline of improvements in feeding equipment

1.1.8 Segregation of Raw Materials on Palettes

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Raw Material Pier and Ore Yard



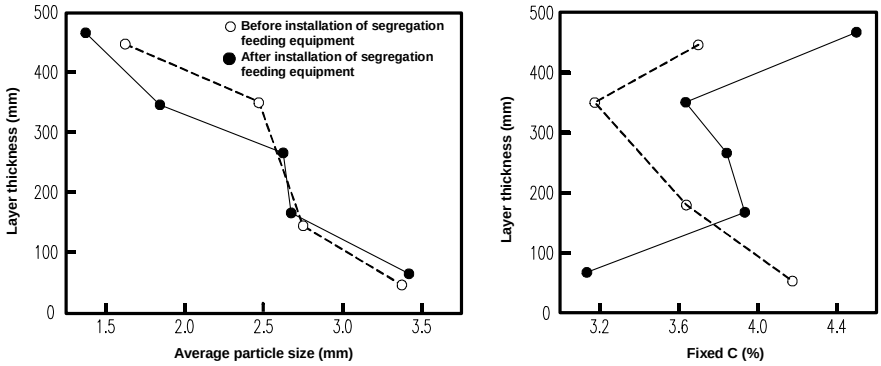
Raw material pier and continuous unloader (3000t/2100t/h)



Iron ore yard

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- ***Comparison of segregation of raw material on palettes***

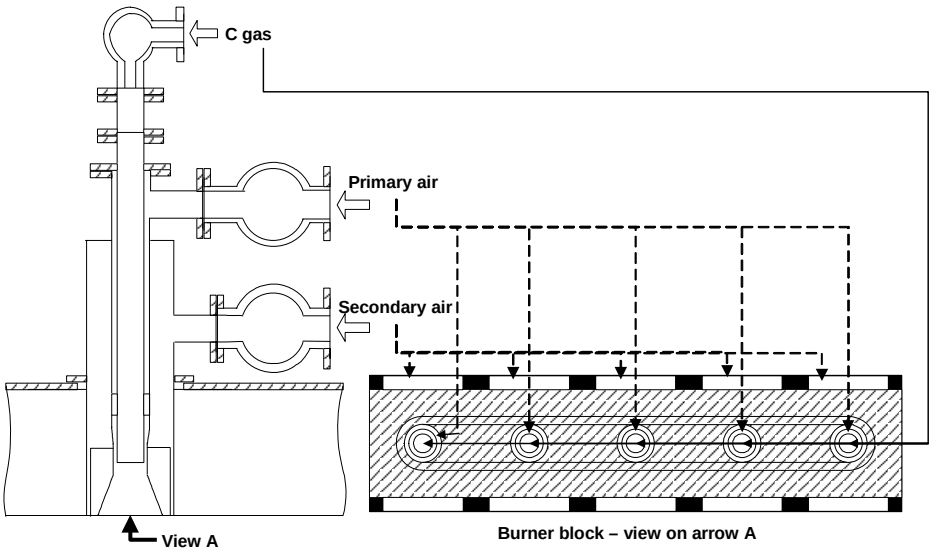


Comparison of segregation of raw material on palettes (granulated particle size, Fixed C)
(No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

1.1.9 Multi-slit Burner in Ignition Furnace

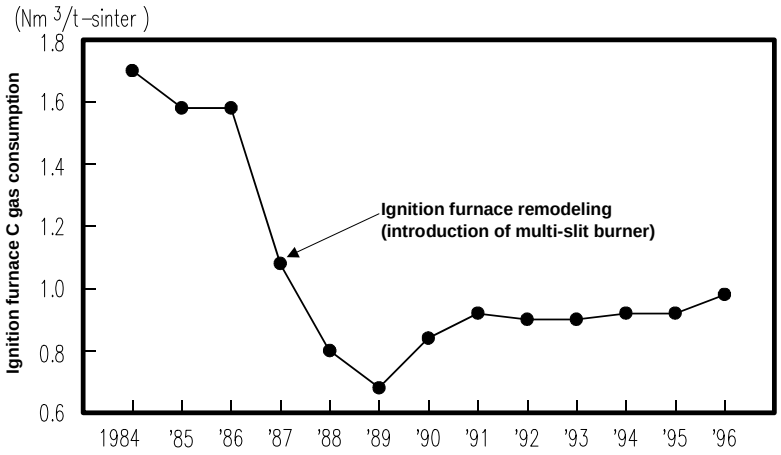
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- ***Outline of multi-slit burner in ignition furnace***



Outline of multi-slit burner

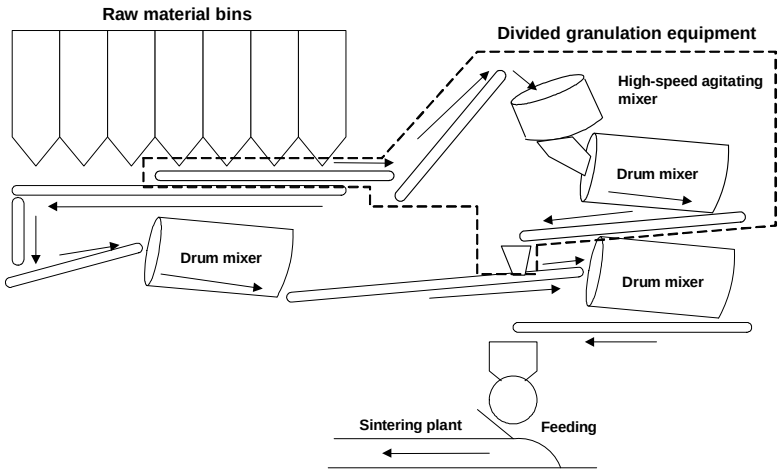
- ***Before/after comparison for introduction of multi-slit burner***



Transition of ignition furnace C gas basic units
(No. 5 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

1.1.10 Equipment to Reinforce Granulation

- ***Outline of equipment to reinforce granulation***



Outline of equipment to reinforce granulation
(No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

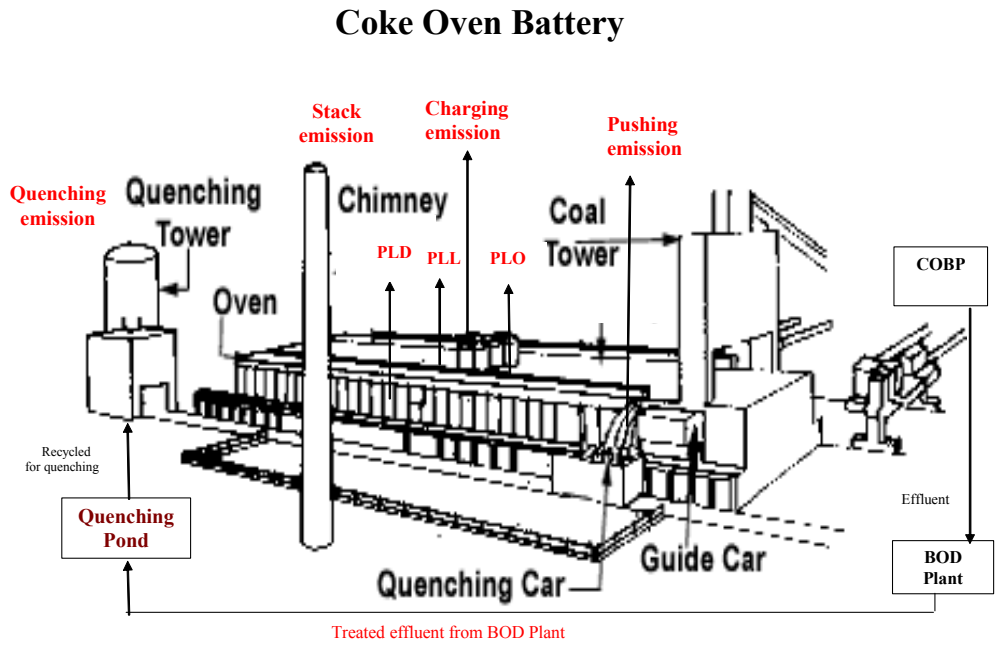
- ***Before/after comparison of granulation reinforcement***

Item	Before reinforced granulation	After reinforced granulation
Water content in raw material (%)	7.0	7.3
Productivity (t/day? m^2)	42 / 38 / 34 — 34.7 → 38.3	
Granulation rate (%)	40 / 32 / 24	
Permeability (J.P.U.)	30 / 28 / 26	
Flame front speed (mm/minute)	32 / 28 / 24	
Return fine (%)	14.0 / 14.0 / 13.6	

Comparison of operation before and after the installation of equipment to reinforce granulation (No. 4 Sintering Plant, Wakayama Steel Works, Sumitomo Metal Industries)

2. Cokemaking - Background

India Best Available Technologies for Cokemaking



India Best Available Technologies for Cokemaking

❖**Cokemaking**

Integrated steel plants in India were set up mainly in the 1960s and 70s and subsequently these were expanded and modernized. The pollution control facilities provided were basically aimed at process requirements rather than the control of pollution. There were no emissions/discharge standards for coke manufacturing units till 1995, except for CO emission (3 kg/ton of coke) and stack emission standards (50 mg/Nm^3). In 1996, the Govt. of India released the standards for coke manufacturing units (notification enclosed). Prevalent technology include concentric top charging, stamp charging and one non-recovery type oven complex.

In the absence of indigenously available coke oven designers and also the equipment and technology suppliers, Indian steel industries are facing great difficulties in achieving the standards. Due to this reason, a model battery meeting all the standards has yet to be built.

Similarly, is the case of the treatment of effluents arising from the Coke Plant. All steel plants have installed effluent treatment plants, which are not functioning efficiently to meet the standards for ammonia and cyanide consistently. These units also need revitalization, keeping in line with the stringent standards. However, with the advent of new green field steel making facilities, non-recovery type coke ovens are slated to be installed.

Assistance needed :

- ➢Modern and improved design of battery machines
- ➢Self sealing leak proof oven doors and their maintenance practices
- ➢Hydrojet/other suitable door and frame cleaners at end benches
- ➢Improved askania control system
- ➢Pushing and charging emission control system
- ➢Modern quenching tower with required facilities
- ➢Facilities for smooth and efficient running of BOD Plants

2.1 Super Coke Oven for Productivity and Environmental Enhancement towards the 21st Century (SCOPE21)

Japan - Best Available Technologies for Cokemaking

Objective

1. Elimination of the following problems of conventional cokemaking process:
   - a narrow choice of coal sources
   - low productivity
   - environmental pollution
   - large energy consumption

2. Development of the innovative cokemaking process for replacement of existing coke ovens.

Japan - Best Available Technologies for Cokemaking

Targets of the SCOPE21

1. Increasing the ratio of using poor coking coal from 20% to 50%.
2. Higher productivity for reducing the construction costs.
3. Reducing NOx by 30% and to achieve no smoke and no dust.
4. Saving energy by 20% which contributes to reducing CO_2

Development step for commercialization of the SCOPE21 process

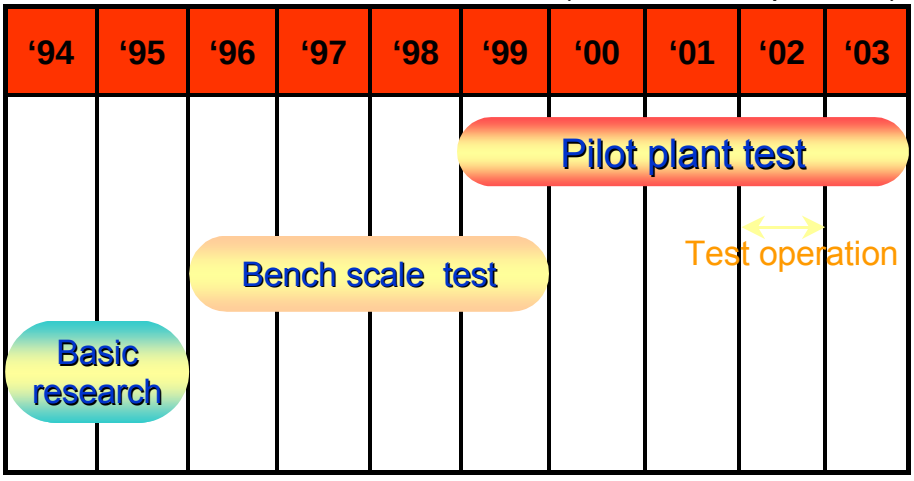
Scale of test plant		Coal pretreatment process	Coke oven
1st	B.P.	0.6t/h (1/200□ C.P.)	Combustion chamber (Actual scale test)
2nd	P.P.	6.0t/h (1/20□ C.P.)	1 coke oven (½ length)
3rd	C.P.	**240t/h** (120t/h□ 2set)	34t/oven□ n

B.P : Bench scale plant
P.P : Pilot plant
C.P : Commercial plant

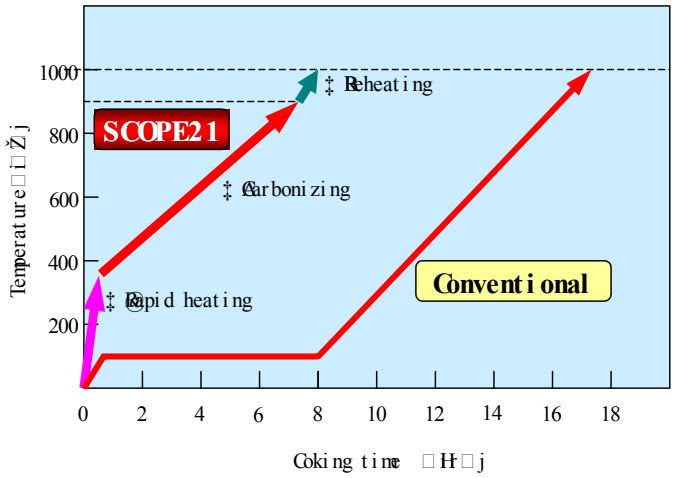
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SCOPE21 development schedule

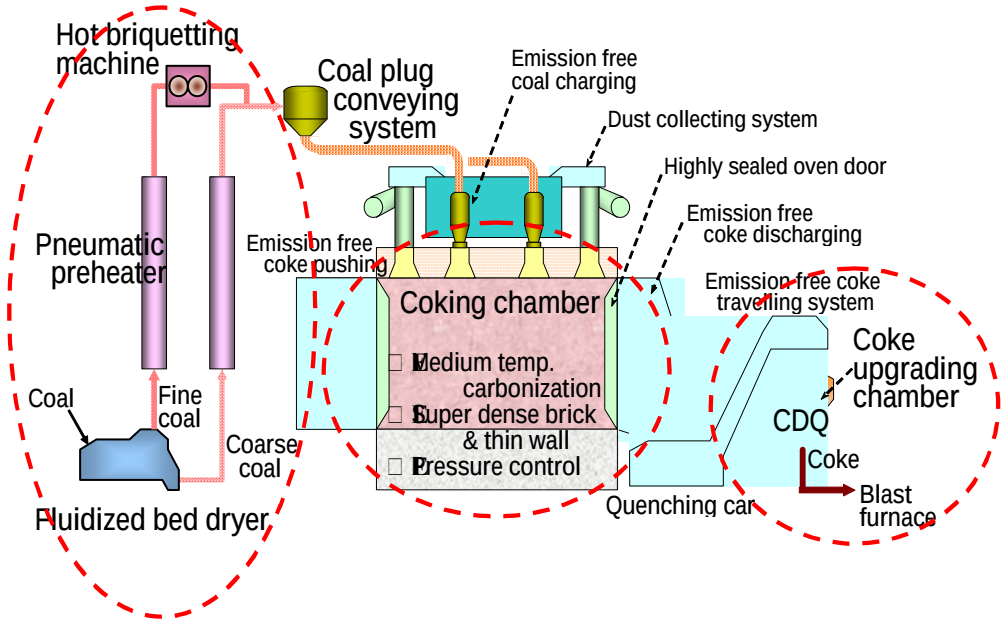
(Fiscal Year;Apr.-Mar.)



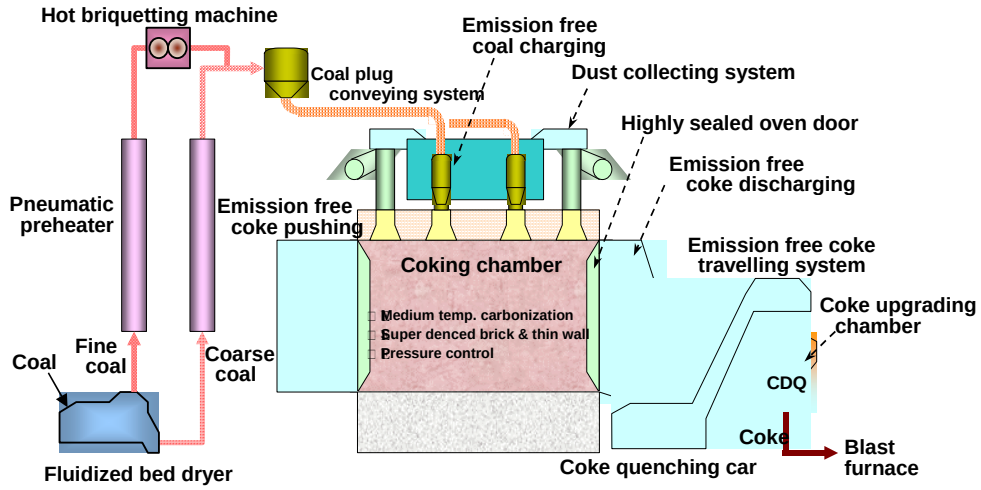
Carbonization Image of SCOPE21



SCOPE21 Process Flow



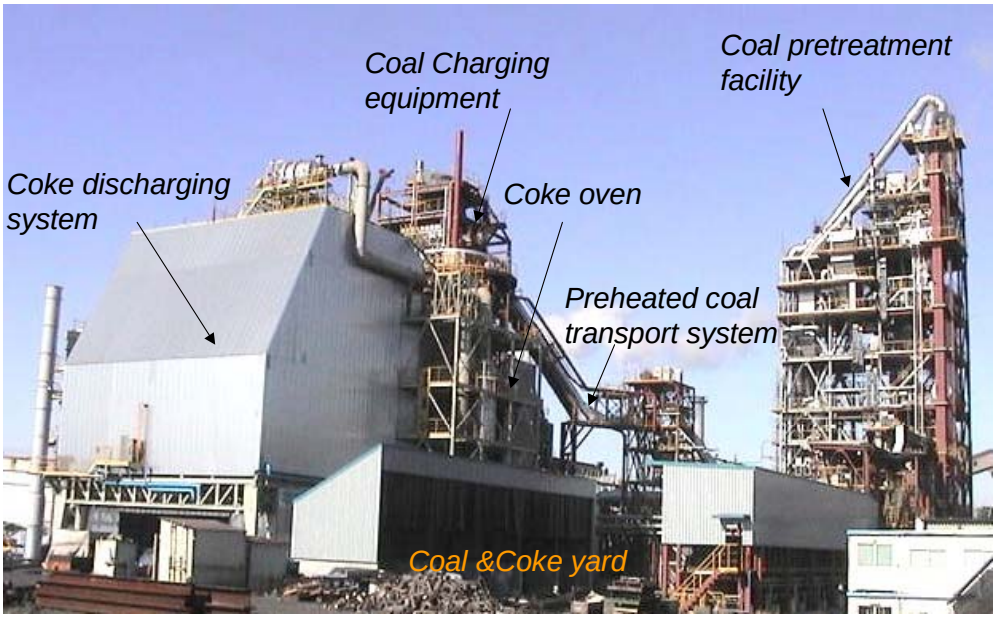
Schematic diagram of the SCOPE21 process flow



Japan - Best Available Technologies for Cokemaking



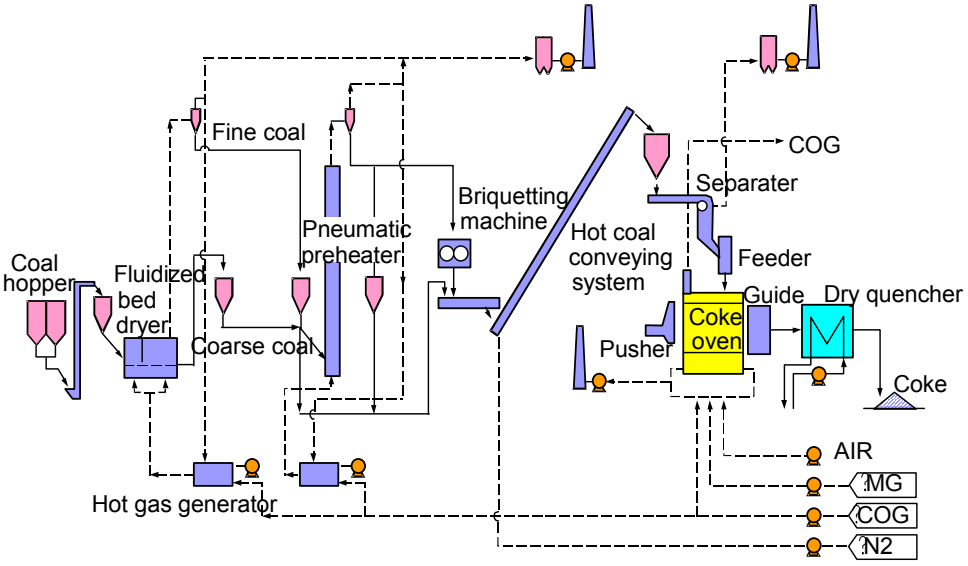
External View of The Pilot Plant 1



External View of The Pilot Plant 2



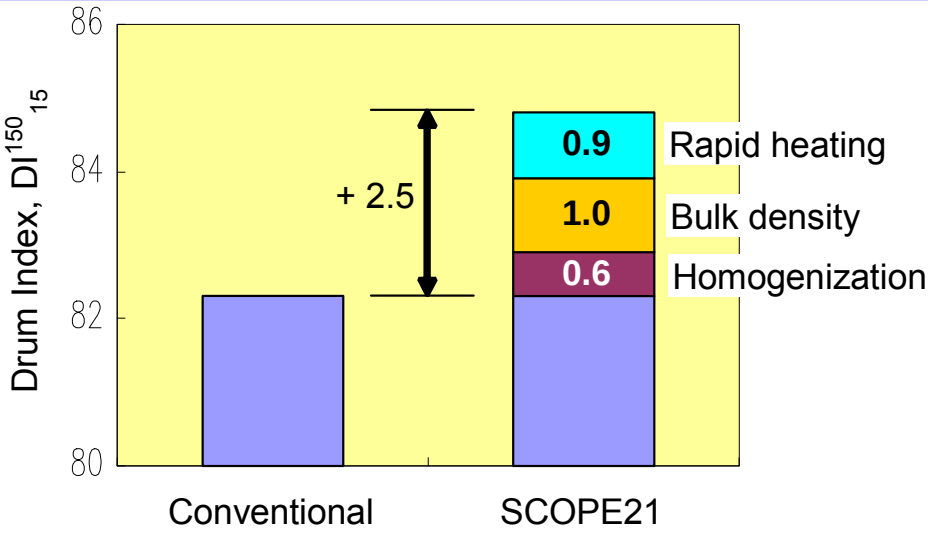
Overall process flow of the pilot plant



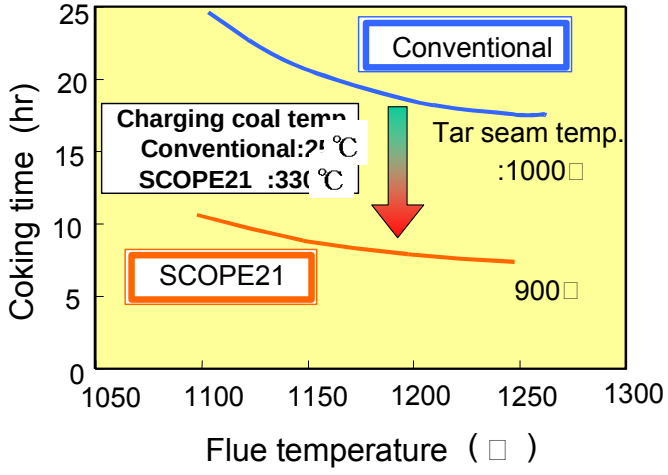
Pushing operation of coke cake



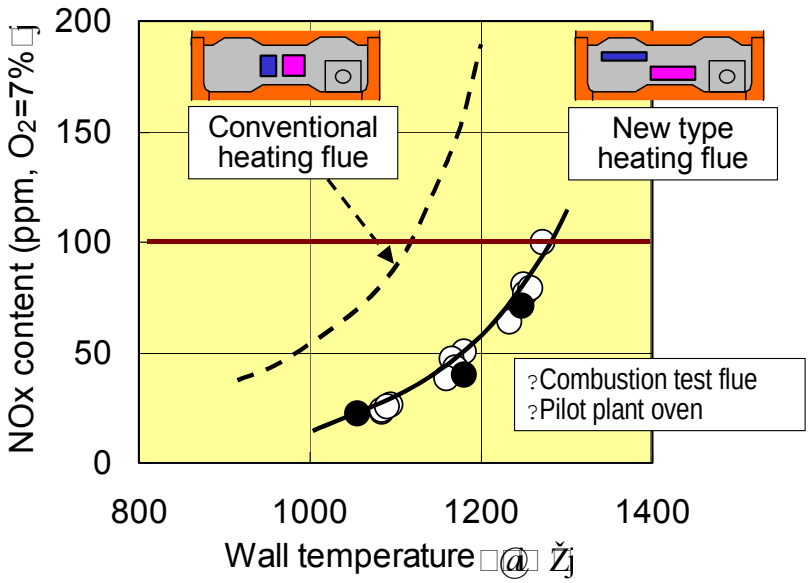
Effect of improvements on the coke strength by the SCOPE21 process



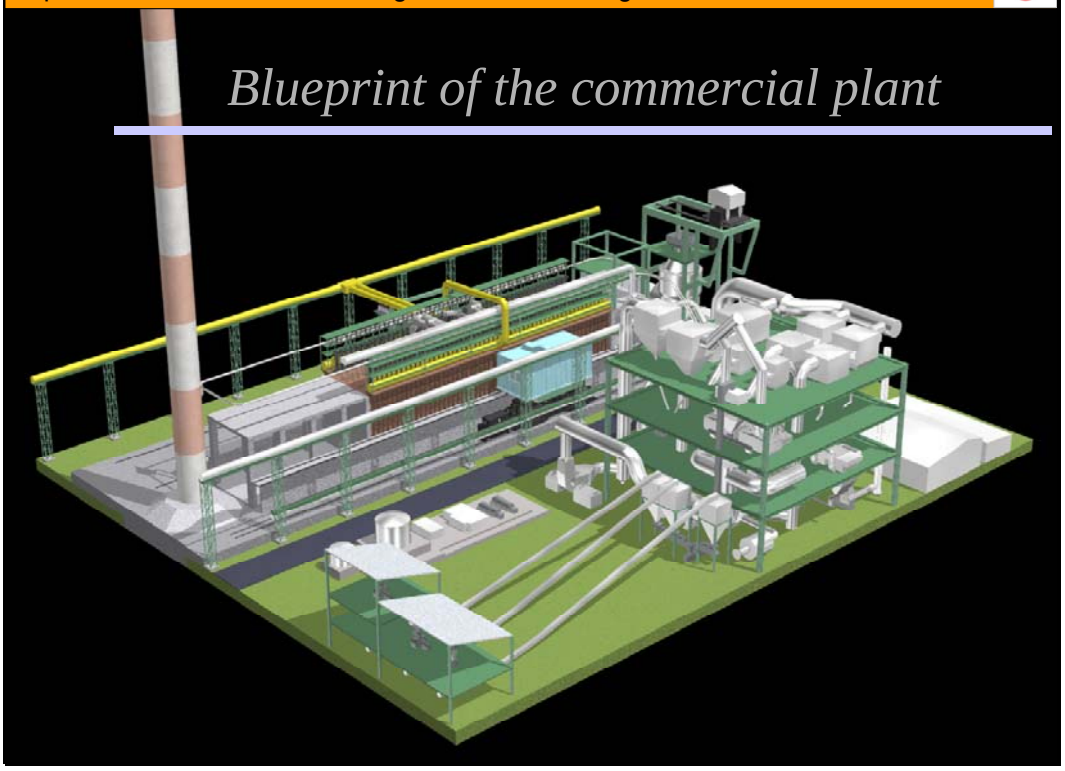
Reduction of coking time by the SCOPE21 process



NOx content



Blueprint of the commercial plant

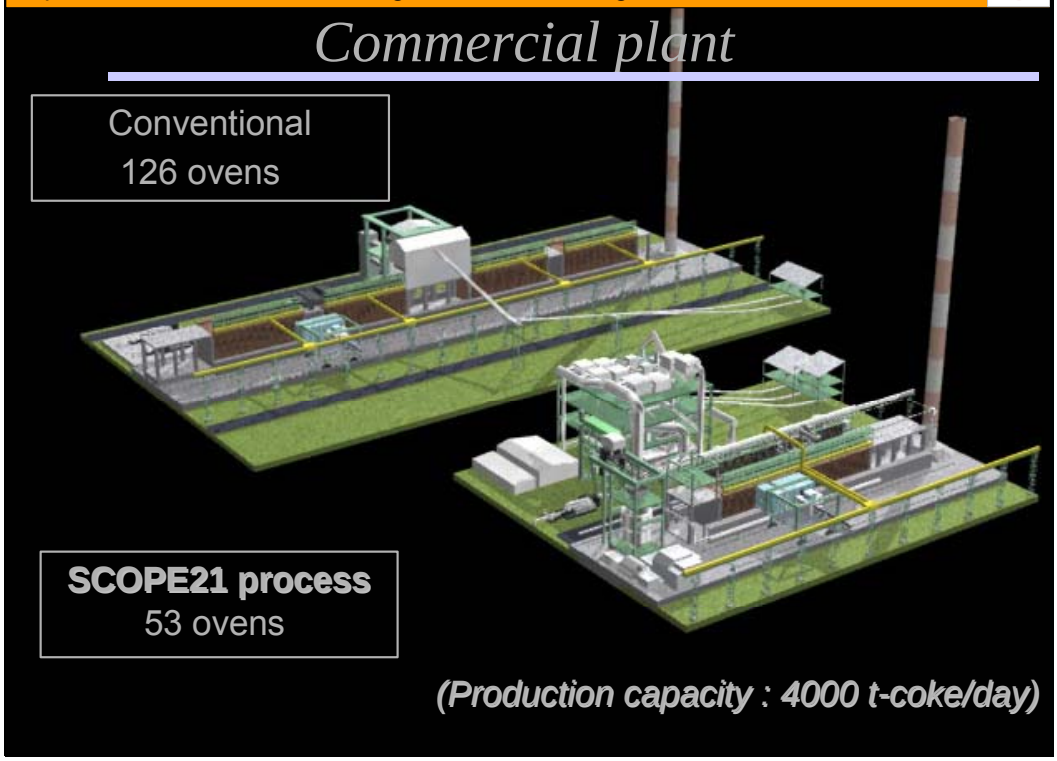


Main specification of SCOPE21

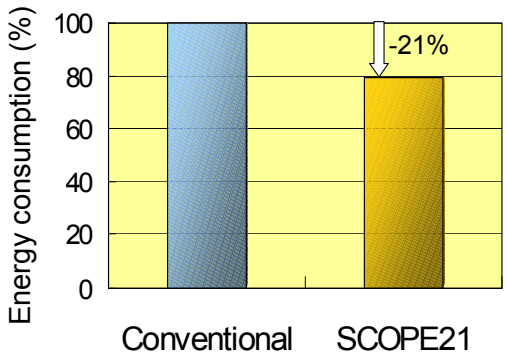
		Conventional(ref.)	SCOPE21
Charging coal	Moisture	9.0	0
	Temperature	25	330
Coke oven operation	Flue temp.	1250	1250
	Coking time	17.5	7.4
	Productivity	1	2.4
Coke oven basic specifications	Dimensions	7.5 16L 0.45W	7.5 16L 0.45W
	Wall brick	dense silica Thickness =100	super dense silica Thickness =70
	Number of ovens	126	53

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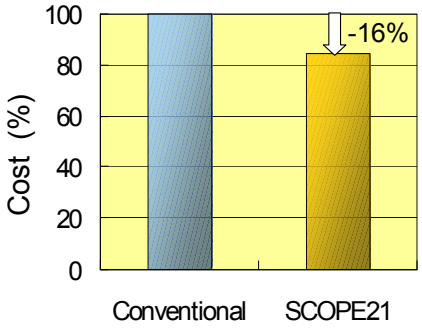
Commercial plant



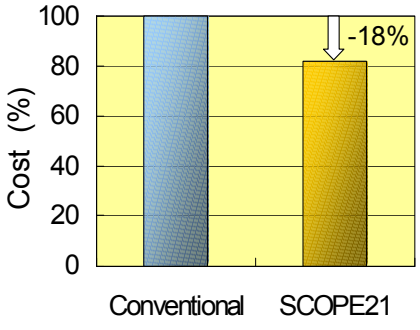
Energy saving by the SCOPE21 process



Reduction of the cost by the SCOPE21 process



Construction cost



Coke production cost

Summary (1)

Confirmed the concept of SCOPE21

- Poor coking coal use increase up to 50%.
- Productivity increase 2.4 times without carbon trouble.
- NOx content reduced to one third.
- Energy consumption reduced by 21%
- Production cost will reduce by 18%

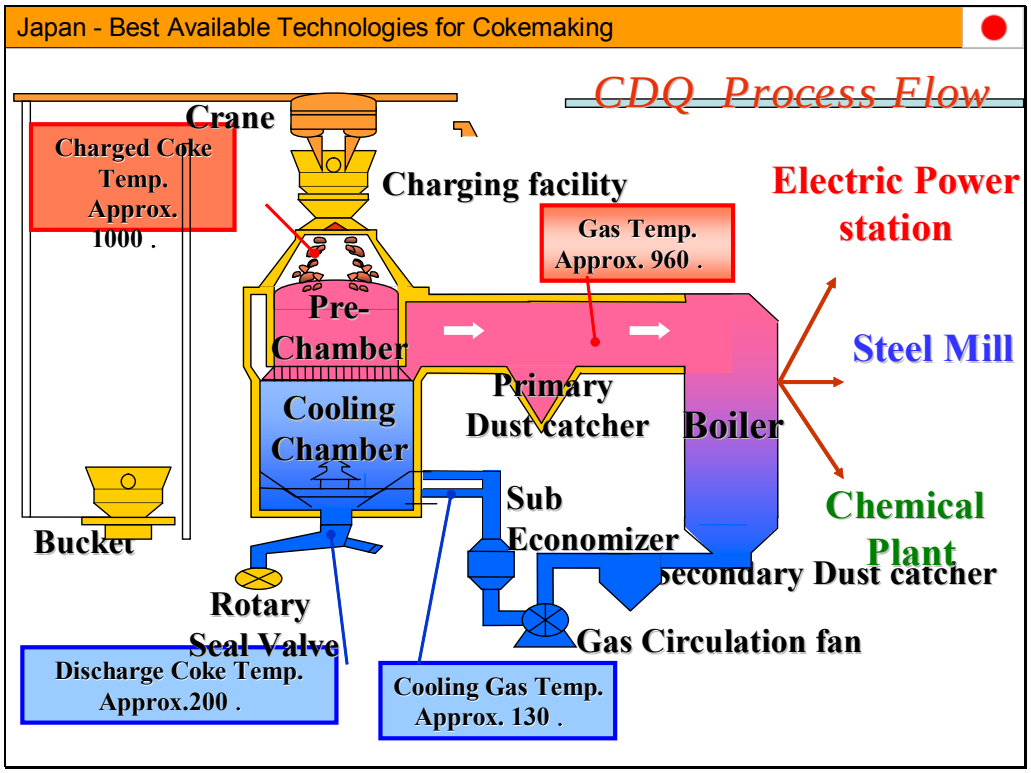
Japan - Best Available Technologies for Cokemaking

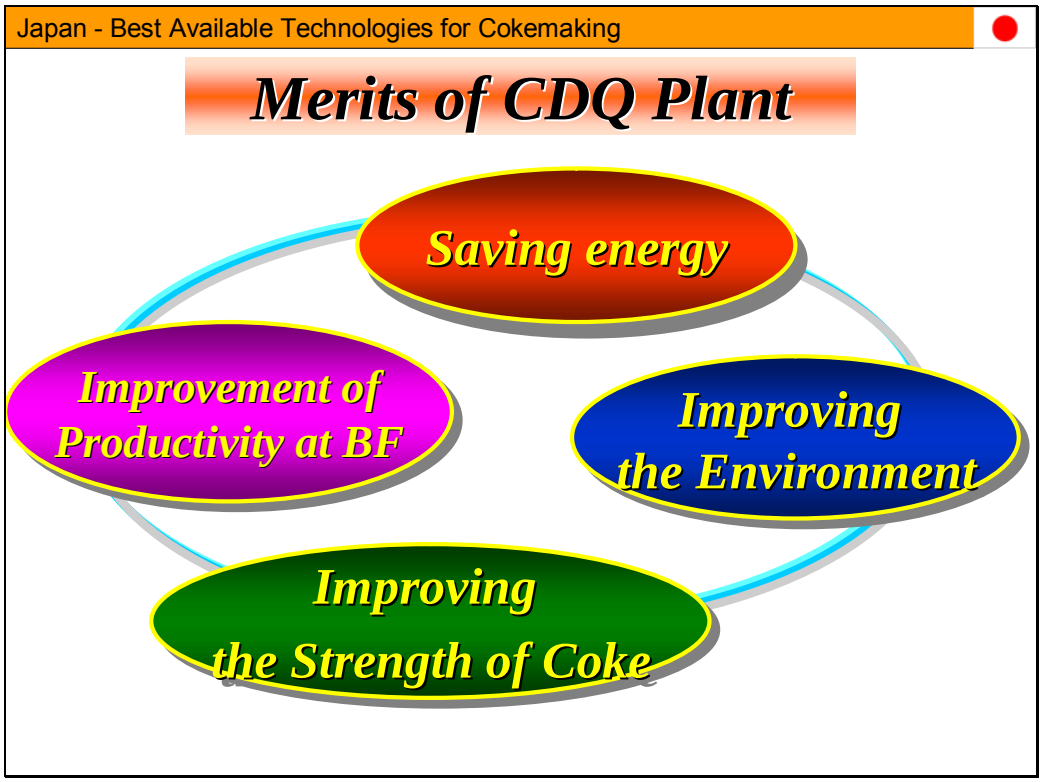
Summary (2)

1. The basic technologies of SCOPE21 process were established by 10 year national program.

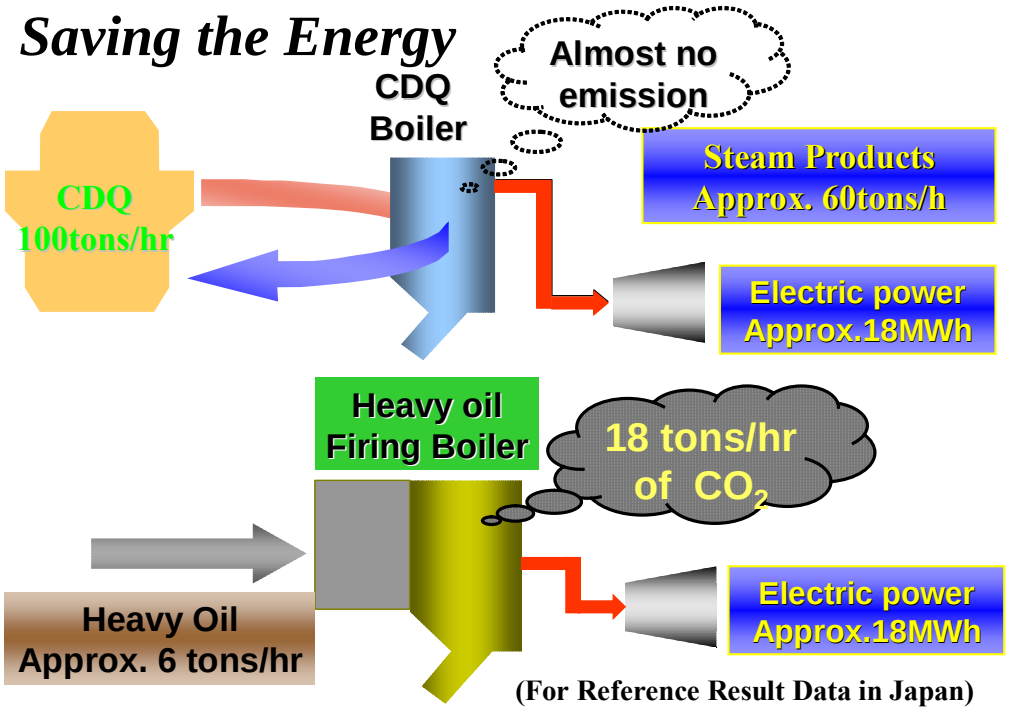
2. The SCOPE21 process has great advantages over the conventional process.

2.2 Coke Dry Quenching





Saving the Energy



(For Reference Result Data in Japan)

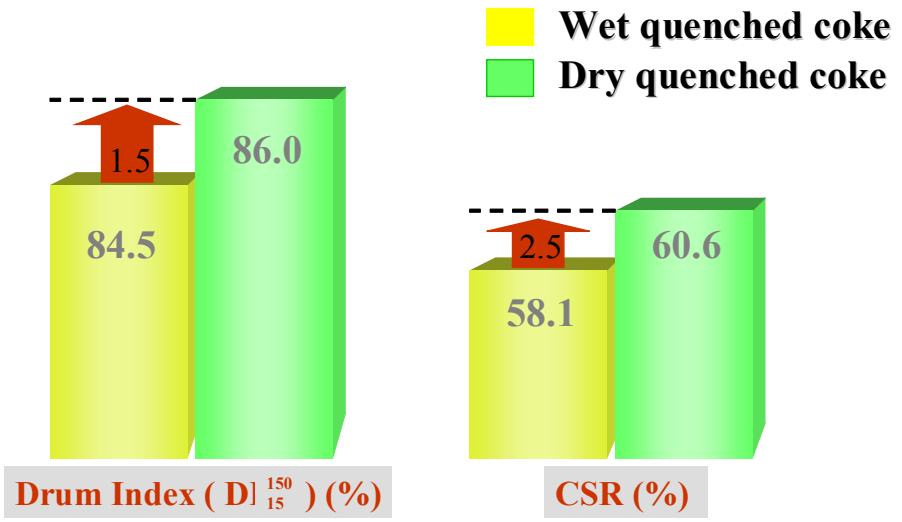
Japan - Best Available Technologies for Cokemaking

Improving the Environment

	Emission (g/t-coke)	Gas (Nm^3/t-coke)
Wet quenching	200 . 400	Steam approx. 700 CO and CO_2 approx. 2
CDQ	Less than 3	———

(For Reference Result Data in Japan)

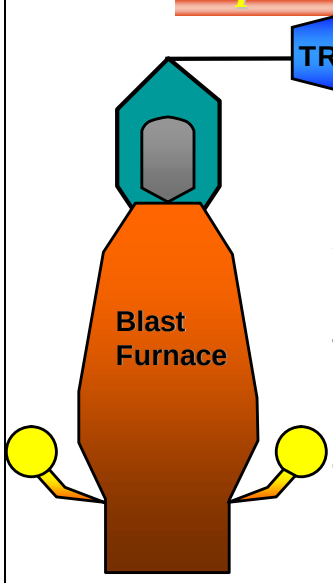
Improving the Strength of Coke



CSR:Coke Strength after CO2 Reaction

(For Reference Result Data in Japan)

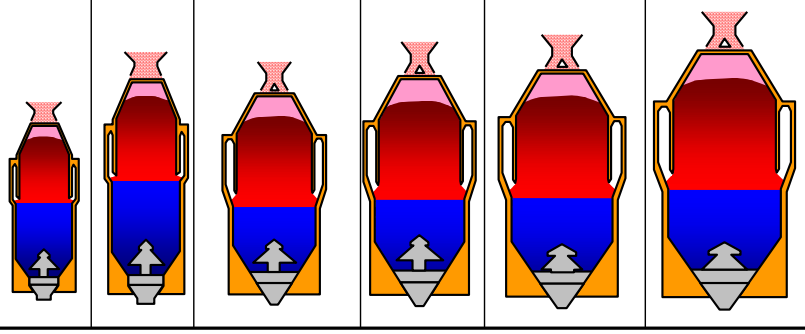
Improvement of Productivity at BF



1. Effect of reducing fuel ratio
2. Increase of iron production
3. Increase of furnace top temperature
   (Increase of Recovering Energy by TRT)
4. Increase of pulverized non-coking coal injection

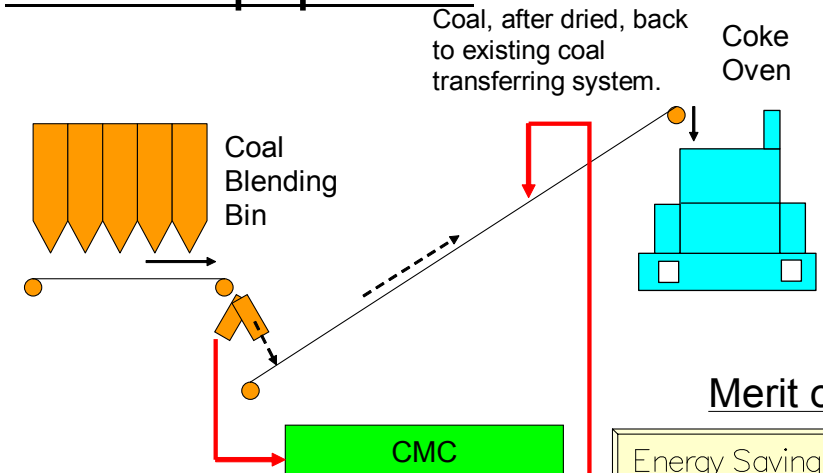
. TRT: Top pressure gas Recovery turbine

The Transition of CDQ Capacity

Operation Start	1974							1987	1988
Capacity (ton/h)	56	75	110	118	150	180	175	200	200
Profile									

2.3 Coal Moisture Control

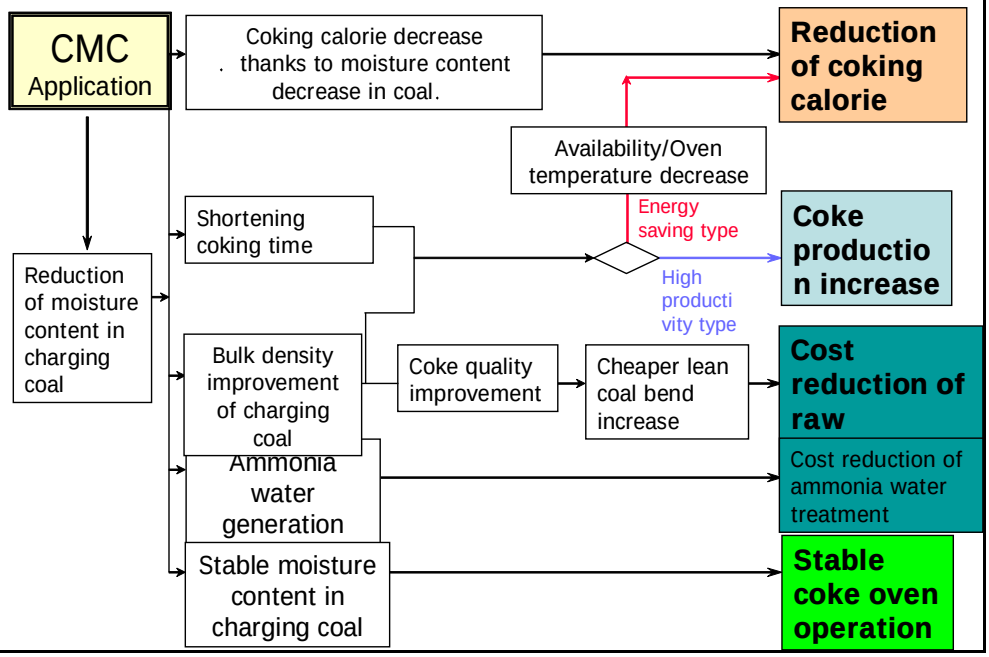
CMC Equipment



Merit of CMC

- Energy Saving of Coke Oven
- Coke Quality Improvement
- Coke Production Increase

Merit of CMC



Japan - Best Available Technologies for Cokemaking

Reference:
Merit of Coke Oven Waste Heat Recovery type CMC

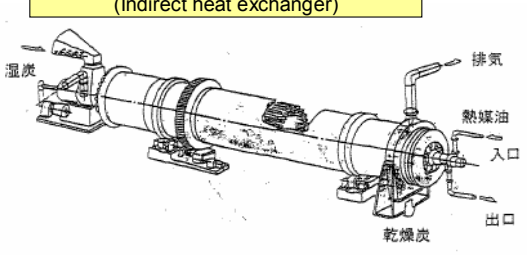
(Actual case of coke ovens in Japan when the moisture content is reduced by 4%)

Energy Saving of Coke Oven	About 340MJ/t-coal
Coke Quality Improvement . DI150/15)	About 1.7%
Coke Production Increase	About 11%

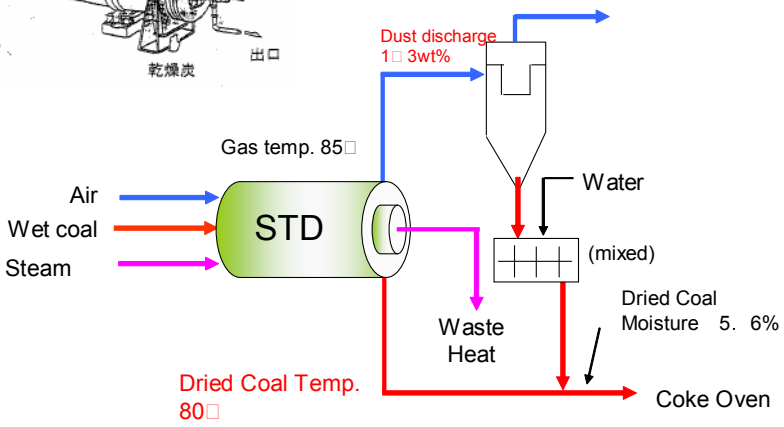
Fifth International Iron and Steel Congress (1986) p312

Dryer type of CMC system 1

Steam Tube Drier. STD)
(Indirect heat exchanger)

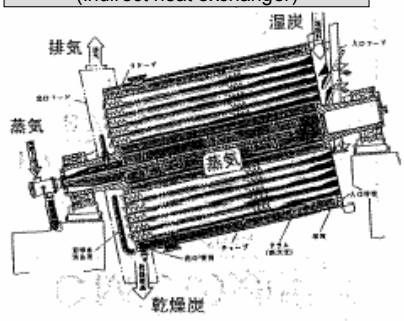


. Steam is inside tube.
. Drum is turning at about 3rpm.
. Many tubes made of special stainless
. Condensate of wet coal moisture is sulfur contents.

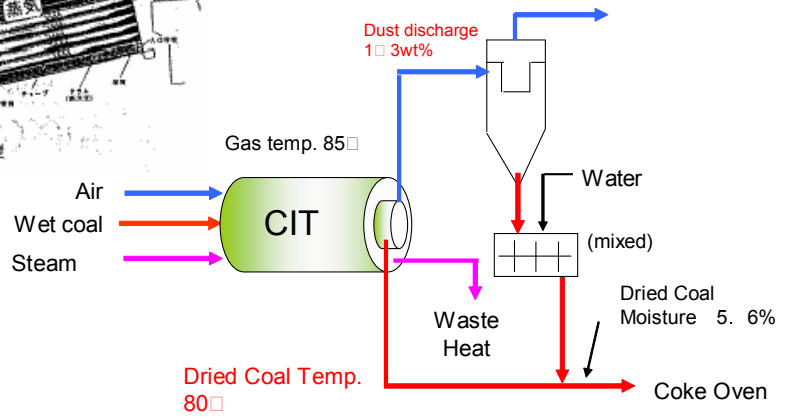


Dryer type of CMC system 2

Coal In Tube Dryer (CIT)
(Indirect heat exchanger)

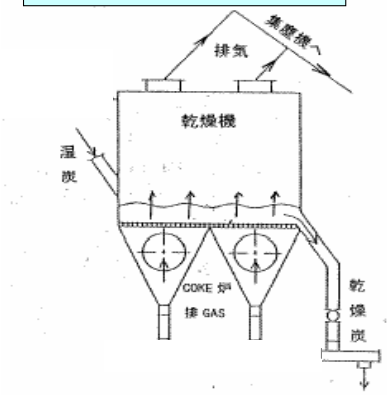


. Coal is inside tube.
. Drum is turning at about 10rpm.
. Big bearing and many tubes.

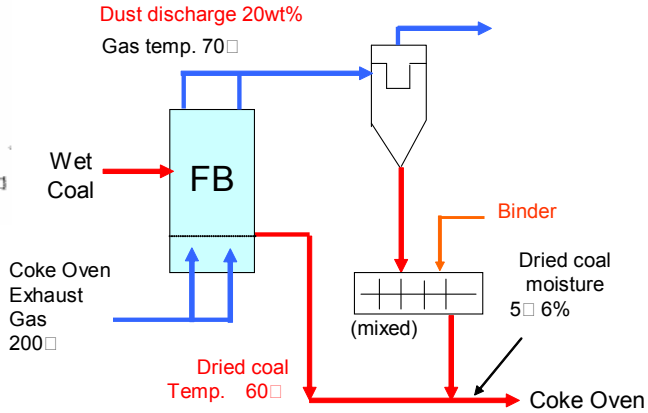


Dryer type of CMC system 3

Fluidized Bed (FB)
(Direct heat exchanger)



- Coal is fluidized and dried.
- No drum turning..
- Simple and maintenance-friendly structure.



Comparison of CMC Drying Method

Type	**Steam Tube Dryer** 1st generation	**Coal In Tube** 2nd generation	**Fluidized Bed** 3rd generation
Drying method	Multi-tube, steam inside, indirect heat transfer	Multi-tube, coal inside, indirect heat transfer	Fluidized Bed, direct heat transfer
Heat resource	Steam	Steam	**Coke oven Exhaust gas**
Material	Special stainless steel	**Carbon steel and usual stainless**	**Carbon steel and usual stainless**
Electricity	**Only for drum turning**	**Only for drum turning**	For blowers
Steam	Using as heat source	Using as heat source	**Only for steam trace**
Maintenance	Maintenance against colosion and abrasion	Maintenance against abrasion	**Easy usual maintenance**
Installtaion in Japan	**6 units**	4 units	1 unit (FB type DAPS :3units)
Notes	Effective using for surplus steam	Effective using for surplus steam	**Reasonable investment** and heat recovery

History of CMC Application in Nippon Steel Gr.

Year	CMC Type
1983	Oita works(□ □) STD
1991	Kimitsu works(□ □) CIT
1995	Yawata works(□ □) CIT
1996	Chong Qing(□ □) STD
	Muroran works(□ □) FB

Decrease of Capital Investment

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Necessary Actions for CMC Application

Coke Oven
Dusting in coal handling operation
Ignition/Dusting in charging coal operation
Carbon generation speed up in coke oven
Increase of maximum inside pressure of coke oven (Gas leak from oven door)
Pushing resistance increase

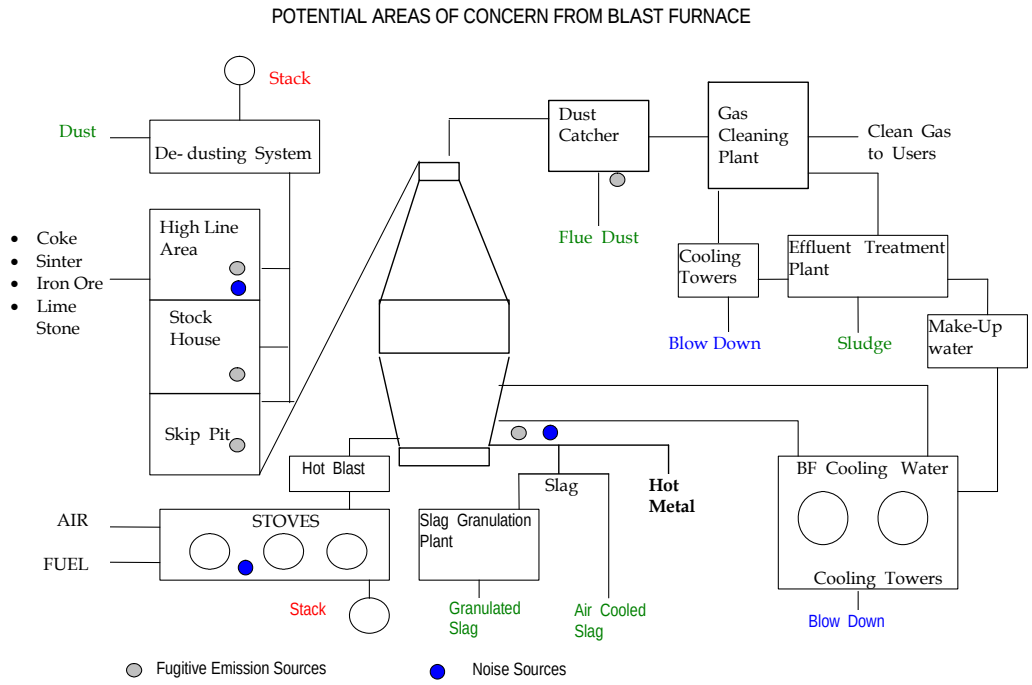
Coke Oven Action

Gas Cleaning
Moisture content increase in tar
Sludge content increase in tar
Deterioration of gas cooler performance

Tar Treatment Action

3.1 Blast Furnace Ironmaking - Background

India Best Available Technologies for Ironmaking



India Best Available Technologies for Ironmaking

❖**Ironmaking**

In the mid 1980s and early 90s, the steel industry underwent modernization keeping in line with the phasing out of energy intensive and pollution prone facilities and enhancing productivity. The major modernization that took place was phasing out Open Hearth Furnaces (OHFs) and steel forming facilities (mill zone). Not much improvement was envisaged in the iron making units, apart from the plan for the augmentation of production. Much later few improvements were made in the processing of feed material and feeding facility (Bell less top). Not much emphasis was given in those days on pollution control facilities in absence of specific environmental standards.

High emission continued from highline/ stock house/ skip areas, as well as during the tapping of hot metal. Presently, plants are planning to replace the ineffective dust evacuation system in the stock house and other areas with the dry fog dust suppression system. The available modern and efficiently performing dust control and sludge control facilities need to be made available for the smooth functioning of existing system.

High noise pollution exists in the Cast House, air pre-heater (Stoves) and the GCPs. Of late, few BFs have been provided with on-site slag granulation facility.

Also, efficient a sludge de-watering facility is not available, and in the absence of this, considerable amount of suspended solids is being discharged to the outfalls, causing additional cost for dredging etc. in the downstream.

The Ministry of Environment and Forests is going to publish new standards and guidelines for pollution control.

Assistance needed :

- ➢Appropriate dust evacuation / suppression system
- ➢Modern and efficient GCP with TRT facility
- ➢Efficient sludge dewatering facility
- ➢Alternate usage and handling of BF slag
- ➢Use of dust and sludge

3.1.1 Top Pressure Recovery Turbine

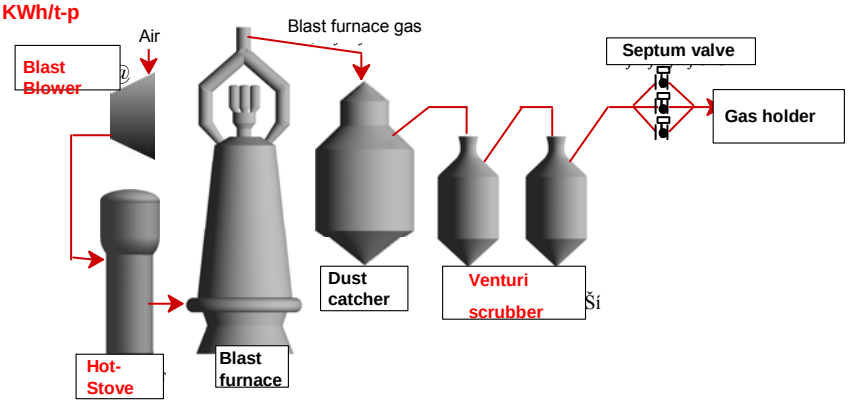
Japan - Best Available Technologies for Ironmaking

1. TRT Overview and Wet TRTs

(1) Process flow before TRT installation

Power consumption for blast blower

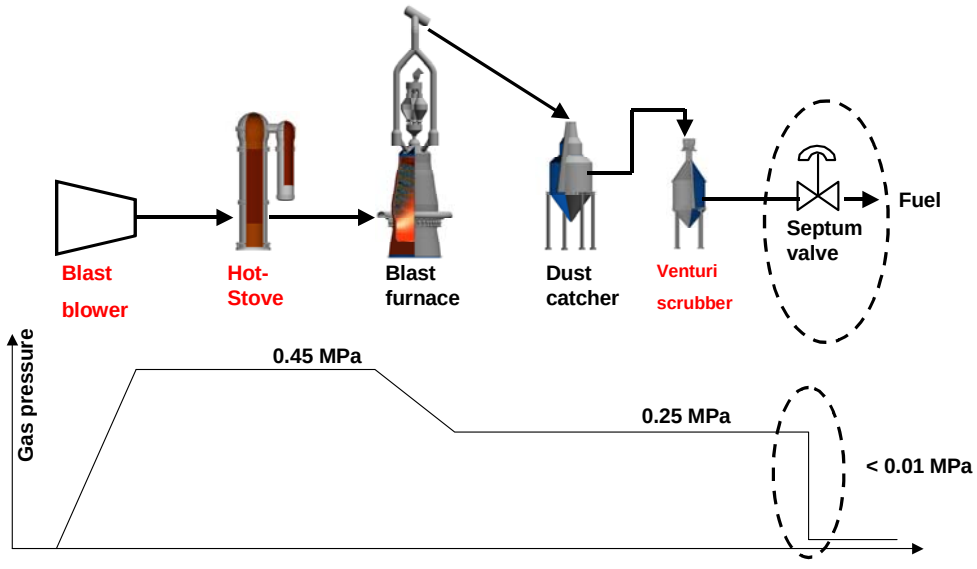
85 KWh/t-p



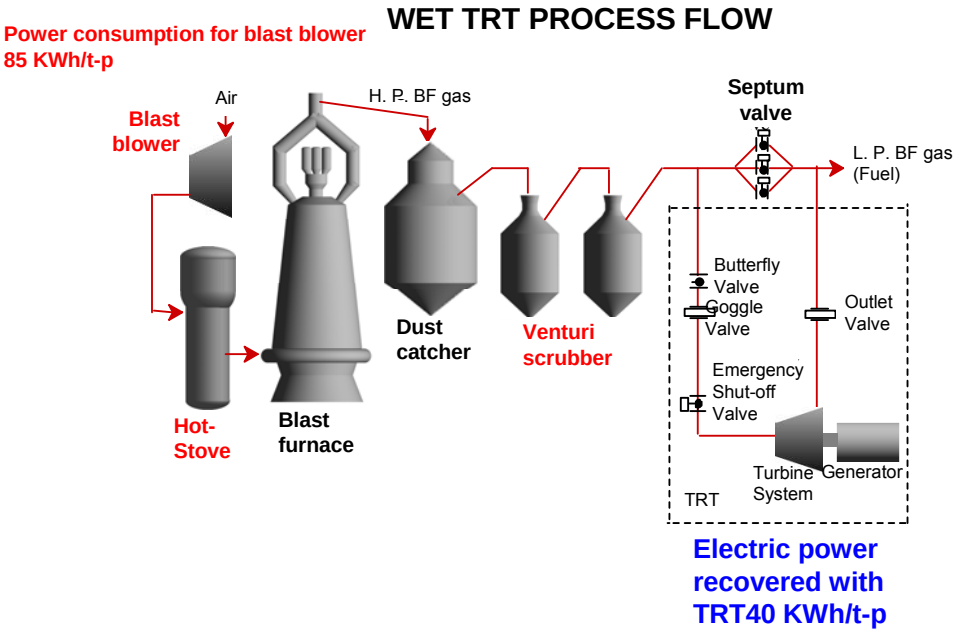
Japan - Best Available Technologies for Ironmaking

(2) Purpose of TRT installation

Recovery of energy from blast furnace gas pressure

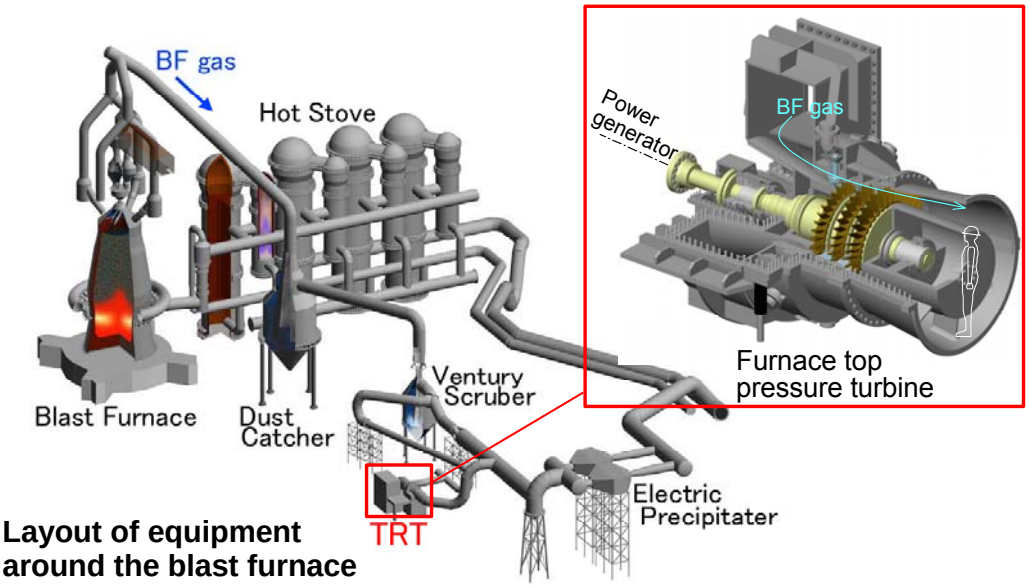


(3) Process flow of wet TRTs



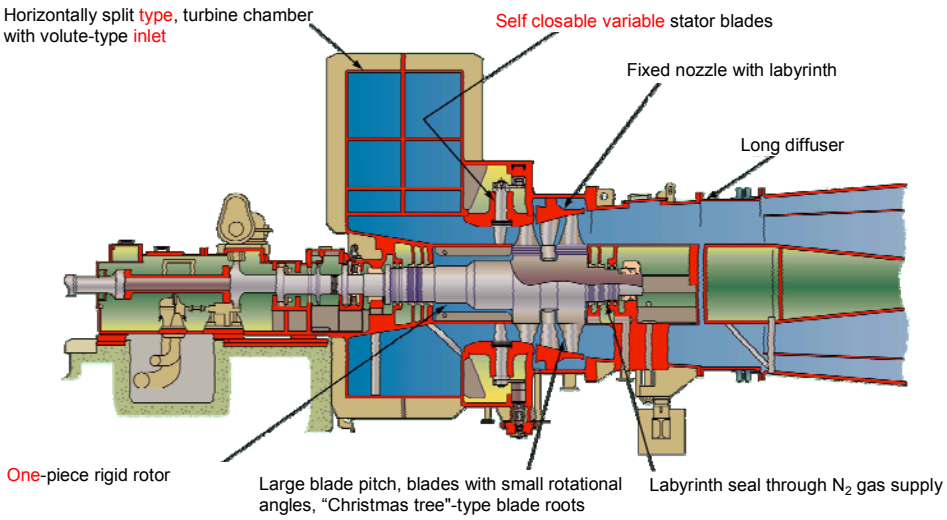
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(4) Layout of wet TRTs



Layout of equipment around the blast furnace

(5) Example for the structure of axial flow TRTs



2. Background for the Dissemination in the Japanese Iron and Steel Industry

(1) Background for the first introduction of TRTs in Japan

Priority issues and countermeasures for the introduction of TRTs

(1) Prevent adverse effects on the operation of the blast furnace (furnace top pressure control)

⇨ **Continue top pressure control of BF with existing septum valve (TRT gas quantity is about 75% of the total)**

(2) Put priority on countermeasures to protect TRT

⇨ **Employ flat plate bladed radial flow turbines that dust does not easily adhere to (efficiency is not so good as axial flow)**

With the above policy, the first TRT was installed in Japan in 1974 to prove the stability of the equipment, as well as the effectiveness for energy conservation.

(2) Background for TRT output improvement

(1) Increase in the quantity of gas passing through TRT

⇒ Employment of furnace top pressure control with using TRTs

(2) Improvement of turbine efficiency

⇒ Introduction of axial flow TRTs

(3) Increase in the gas temperature at the turbine inlet

⇒ Introduction of TRTs with dry type dust collection (dry type TRTs)

(3) Transition in TRT output improvement

Example for an estimation of the transition of TRT output improvement

		Wet radial flow	Wet radial flow	Wet axial flow	Dry axial flow
Blast Furnace top pressure control		Septum valve (GAS 25% by pass)	TRT	TRT	TRT
Blast furnace gas quantity		600,000	600,000	600,000	600,000
Quantity of gas passing through TRT	Nm^3/h	450,000	600,000	600,000	600,000
Furnace top pressure	ata	3.533	3.533	3.533	3.533
Gas temperature at turbine entrance	°K	328	328	328	423
Gas pressure at turbine inlet	ata	3.333	3.333	3.333	3.433
Gas pressure at turbine exit	ata	1.133	1.133	1.133	1.133
Turbine efficiency		0.75	0.75	0.850	0.850
Electric power generated by turbine	KW	10,330	13,773	15,609	20,605
Growth rate of power generated		100%	133%	151%	199%
Basic unit for power generated	KWH/t-p	27.5	36.7	41.6	54.9
Recovery ratio of air blasting power		31.8%	42.4%	48.1%	63.4%

Japan - Best Available Technologies for Ironmaking

1800RPM ROTOR



3600RPM ROTOR



Weight/quantity

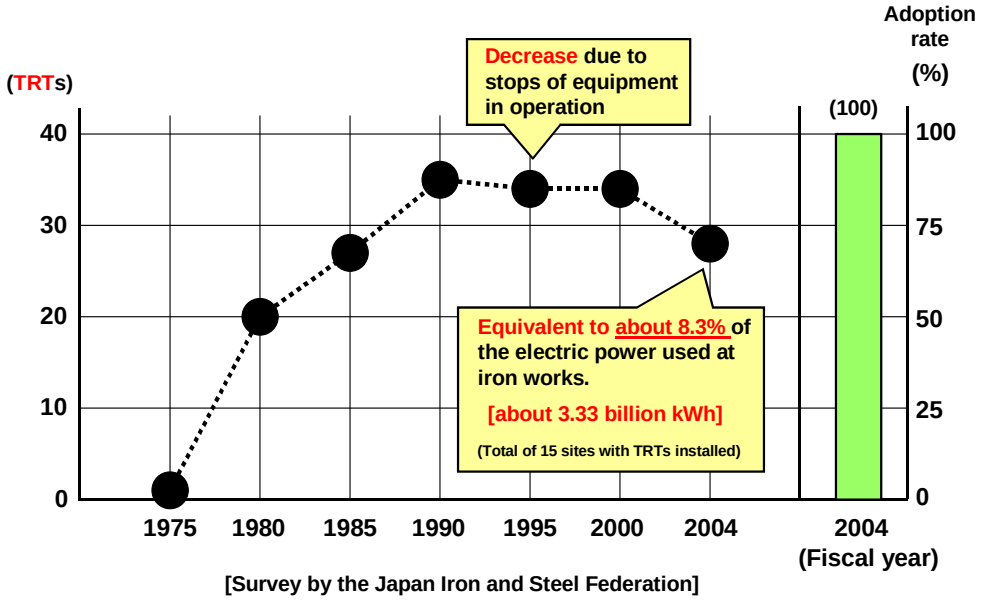
Rotor		16 tons
Rotor blades	Blades of 1st stage	10.9 kg x 41 blades
	Blades of 2nd stage	12.6kg x 41 blades
	Blades of 3rd stage	14.6kg x 41 blades

Rotor		9 tons
Rotor blades	Blades of 1st stage	24.9kg x 25 blades
	Blades of 2nd stage	28.6kg x 25 blades

Japan - Best Available Technologies for Ironmaking

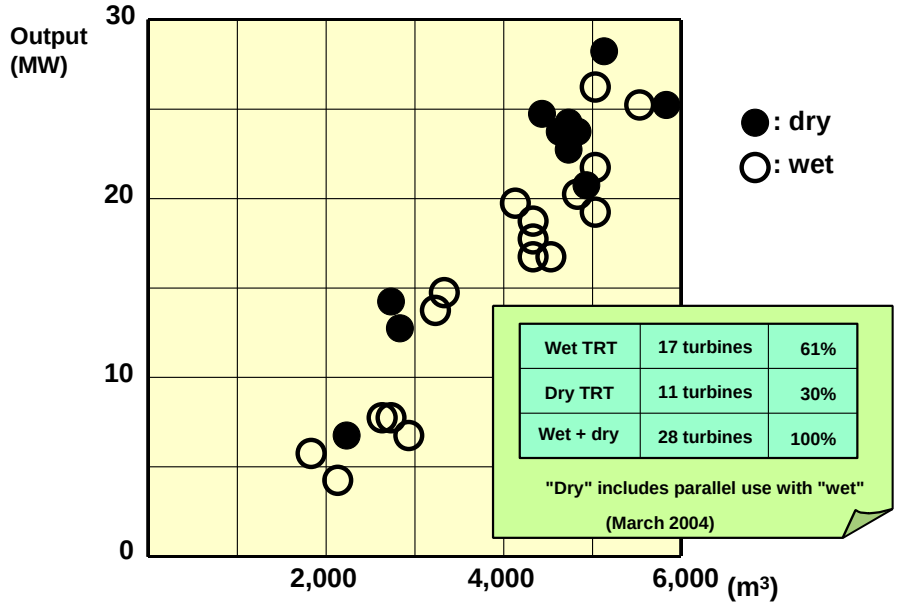
(4) Energy-conservation equipment installed in the Japanese iron and steel industry

Blast furnace top pressure recovery turbine equipment



[Survey by the Japan Iron and Steel Federation]

(5) Relation of Blast Furnace Volume and Permitted TRT Output



[Survey by the Japan Iron and Steel Federation]

3. Dry TRT Systems

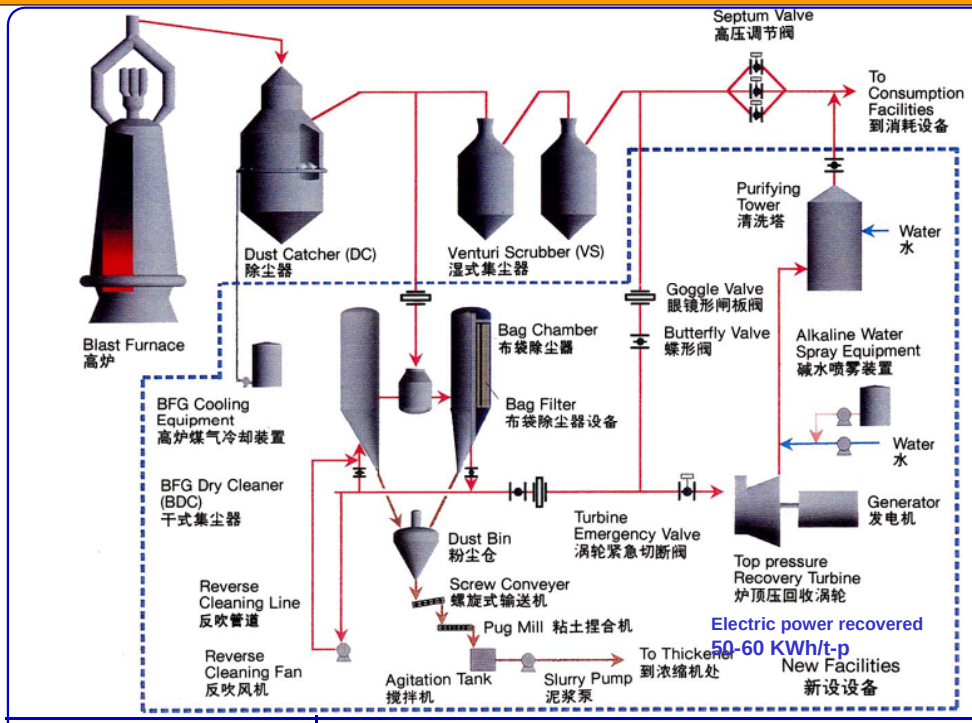
(1) Barriers in the dissemination of dry TRTs in Japan

1) Installation of dry TRT, in case when wet TRT is already installed, means overlapping investment

(Wet TRT)		(Dry TRT)
Wet turbine	→	Dry turbine (replace) Dry precipitator (new installation) * Output improvement 30 - 40%

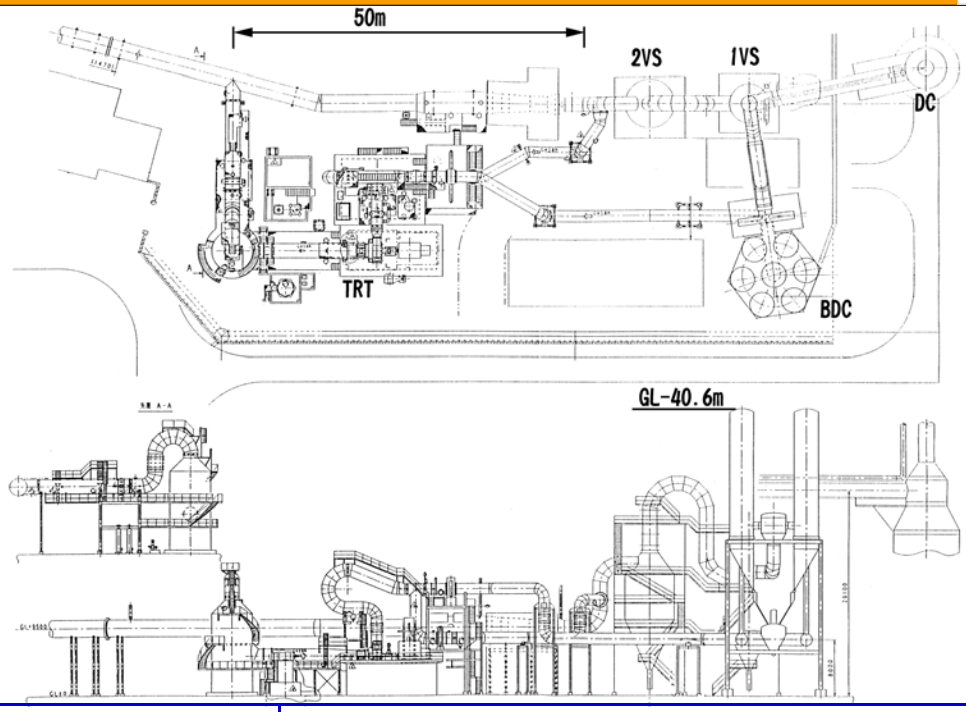
2) There are operational problems that hinder dry TRT

Japan - Best Available Technologies for Ironmaking



Dry TRT Process Flow

Japan - Best Available Technologies for Ironmaking

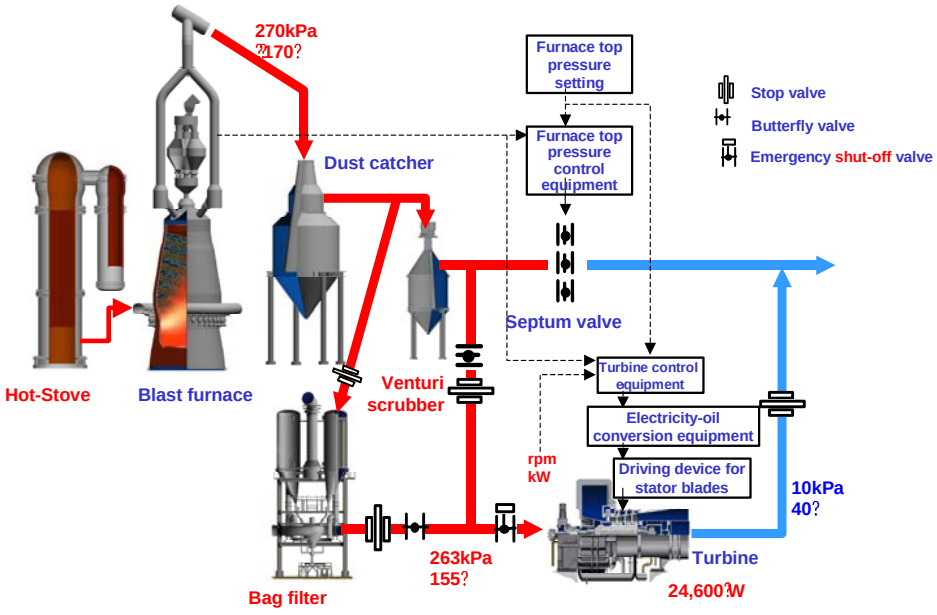


Layout Example for a Dry TRT

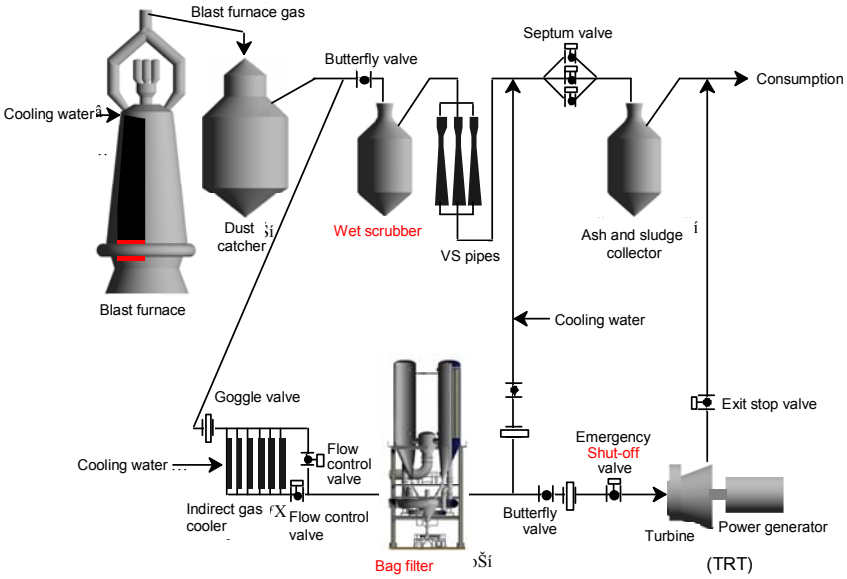
(2) Basic specifications of dry TRT model project

• Blast furnace volume	1,350 m³ (Panzhihua Steel and Iron, Blast furnace No. 4)
• Design blast furnace gas quantity	240,000 Nm³/h
• Design blast furnace gas pressure	0.153 MPa (G)
• Design blast furnace gas temperature	140 °C
• Type of TRT	Adjustable stator blades, 2-stage axial flow (3,000 rpm)
• Type of Dry precipitator	Dry bag filter (6 chambers)
• TRT Output	6,100 kW

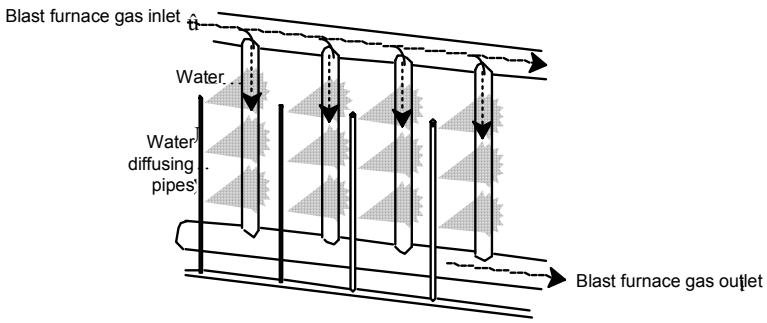
4. Furnace Top Pressure Control Using TRT



(1) Example for an installation of a gas cooler



(2) Gas cooler



5. Points to be considered from Planning to Equipment Management

(1) Main points to be considered when planning a TRT installation

Current status and future forecast for the operational conditions of the blast furnace	Consideration of basic specifications of the TRT
Comprehension of blast furnace gas characteristics	Consideration of dry or wet systems
Comprehension of current status of existing blast furnace gas equipment	Necessary remodeling
Decision on basic policy	Selection of volume and dry/wet

(2) Main points to be considered for operational issue of TRTs

Control of the gas temperature at the turbine inlet	Low temperatures: turbine corrosion High temperatures: filter cloth protection
Comprehension of transition of generated power quantity	Early detection of dust adhesion, wear of blades, etc.
Monitoring of various tendencies	Vibration: indication of serious trouble
Dry and wet operation in parallel is prohibited	Prevention of corrosion trouble

(3) Main points to consider for the maintenance of TRT equipment

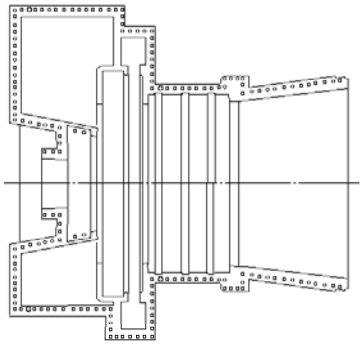
Countermeasures against dust adhesion	Maintenance of precipitator performance Cleaning with high-pressure water
Countermeasures against wear of blades	Maintenance of precipitator performance Sample check of bag filter cloth (dry TRT)
Countermeasures against corrosion	Gas temperature control Coating
Periodical inspections	Early detection of anomalies Prevention of accidents

6. Periodical inspections

Scope and contents of periodical inspections (1)

Upper turbine casing - Penetrant Test (PT)

Inspected item	Inspection item and inspection points	PT for all weld lines in the upper turbine case
	Material of inspection item	SM400
Contents of inspection record	- Existence of deficiencies - Location, pattern, type and classification of the defect indication	

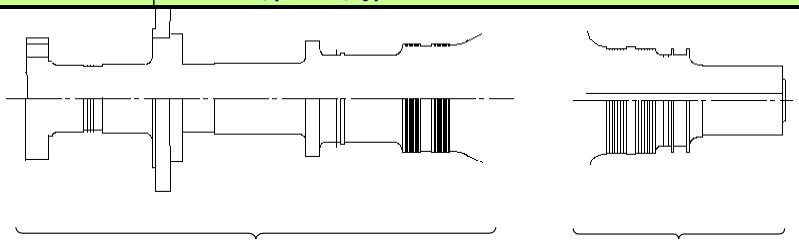


Upper turbine casing

Scope and contents of regular inspections (2)

Main Shaft - Magnetic Particle Test (MT)

Inspected item	Inspection item and inspection points	MT of the gear for the speed governing device of the main shaft, for the shaft bearing and the shaft seal part of the main shaft as a whole
	Material of inspection item	3.5 Ni-13 Cr-Mo Steel
Contents of inspection record	- Existence of deficiencies - Location, pattern, type and classification of the defect indication	



Front part of rotor shaft

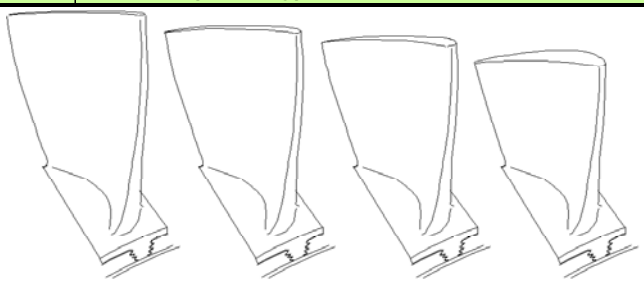
Rear part of rotor shaft

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Scope and contents of regular inspections (3)

Rotor Blades - Magnetic Particle Test (MT)

Inspected item	Inspection item and inspection points	MT for rotor blades
	Material of inspection item	SUS630
Contents of inspection record	- Existence of deficiencies - Location, pattern, type and classification of the defect indication	



Rotor blades of 4th stage

Rotor blades of 3rd stage

Rotor blades of 2nd stage

Rotor blades of 1st stage

7. Conclusion

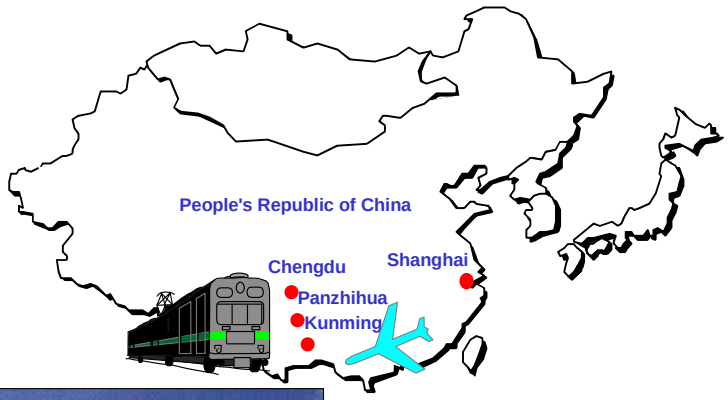
1. Further spread of TRTs in China

2. Effective use of TRTs

→ **Promotion of energy conservation**

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(1) Panzhihua Steel and Iron



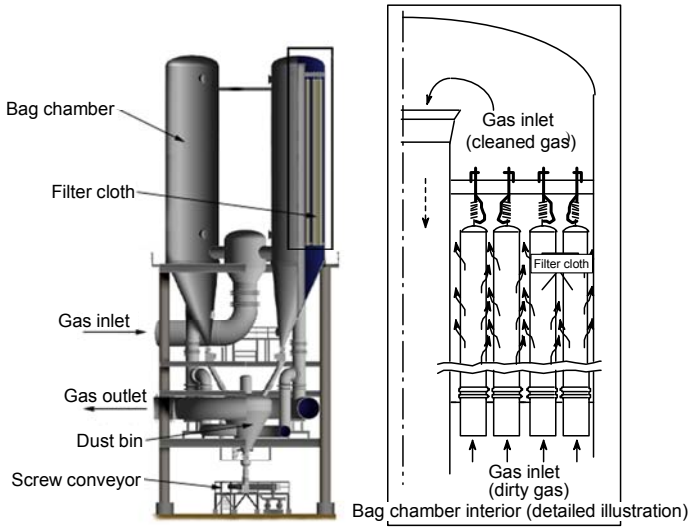


(2) TRTs set up in China

Wet TRT	47	Turbines	94%
Dry TRT (for dry/wet use)	3	Turbines	6%
(Wet + dry)	50	Turbines	100%

(researched in March 2001)

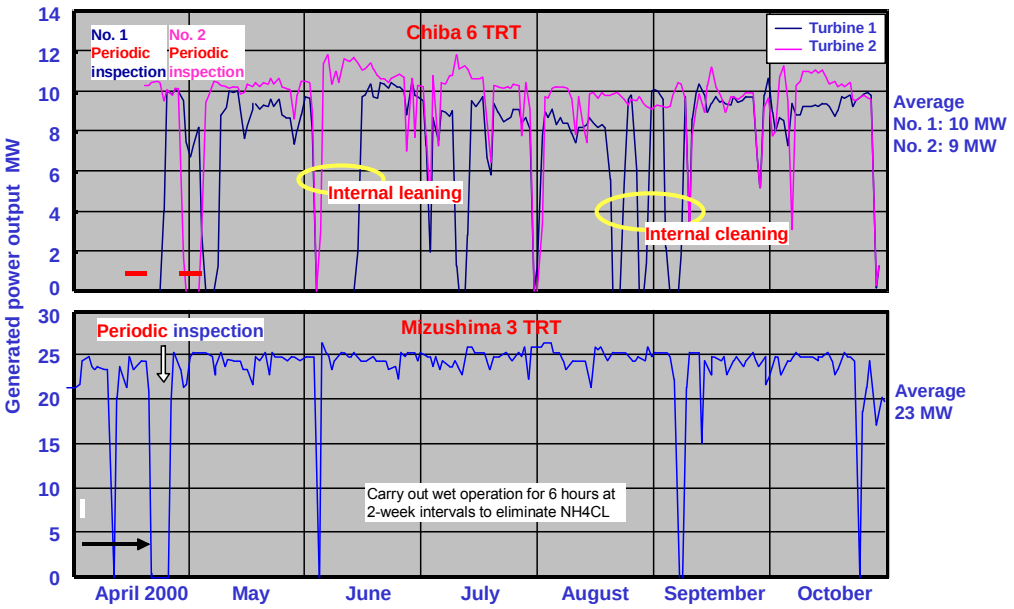
(3) Dry Bag Filter



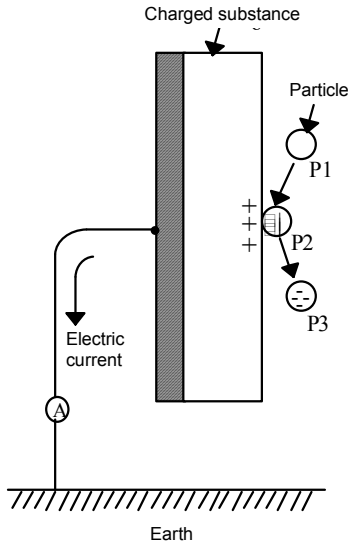
(4) Hindrance Factors for Dry Bag Filter Operation

1) Minimum furnace top gas temperature
   → Dew condensation in interior of turbine
2) Maximum furnace top gas temperature
3) Wet operation before/after BF shutdown
4) Water cleaning of turbine
   → Elimination of NH4CL
5) High PCI operation

(5) Actual Operation of Dry TRTs



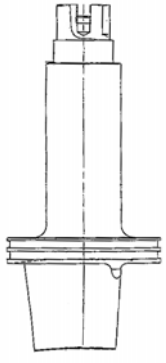
(6) Principle of Dust Monitors



(7)-1) Scope and contents of regular inspections

Adjustable stator blades - Magnetic Particle Test (MT)

Inspected item	**Inspection item and inspection points**	**MT for whole adjustable stator blades**
	Material of inspection item	**13 Cr-Mo Steel**
Contents of inspection record	**- Existence of deficiencies - Location, pattern, type and classification of the defect indication**	

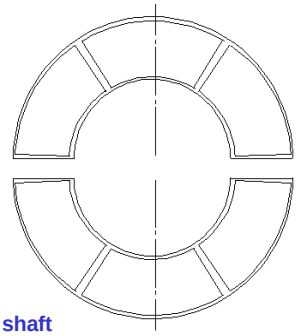


Adjustable stator blade

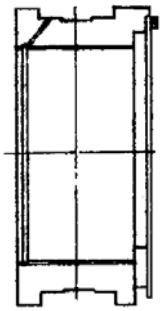
(7)-2) Scope and contents of regular inspections

Shaft bearing - Penetrant Test (PT)

Inspected item	Inspection item and inspection points	PT of white bearing metal
	Material of inspection item	S35CN WL-K
Contents of inspection record	- Existence of deficiencies - Location, pattern, type and classification of the defect indication	



Thrust shaft bearing



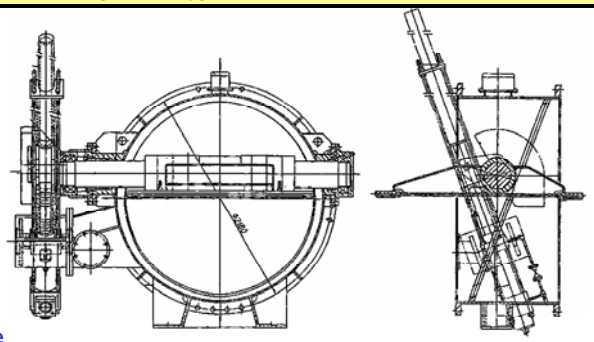
Turbine front/rear

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(7)-3) Scope and contents of regular inspections

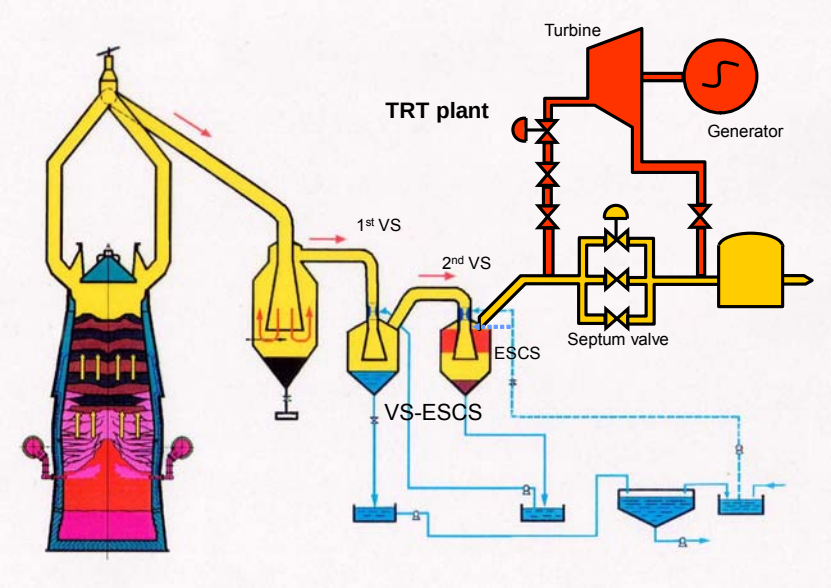
Emergency shutdown valve - Penetrant Test (PT)

Inspected item	Inspection item and inspection points	PT for weld portion of emergency shutdown valve (valve seat)
	Material of inspection item	Valve body: SS400, Valve rod: SUS420
Contents of inspection record	- Existence of deficiencies - Location, pattern, type and classification of the defect indication	



Emergency shutdown valve

Typical flow diagram for high electric energy recovery



Features of VS-ESCS

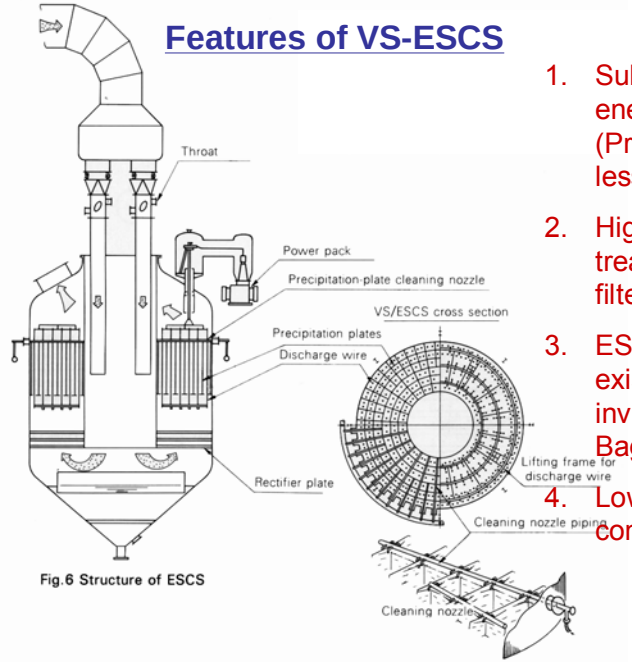
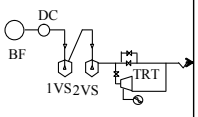
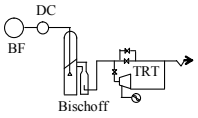
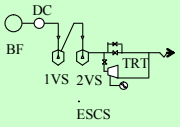
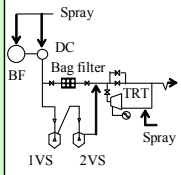


Fig.6 Structure of ESCS

1. Substantial increase in energy recovery by TRT (Pressure loss : 700mmAq or less)
2. Higher temp. gas can be treated compared with Bag filter system
3. ESCS can be installed in the existing 2nd VS and lower investment compared with Bag filter system
4. Lower water consumption compared with other wet type

Comparison of gas cleaning system

Type	Two-stage venturi scrubber	Bischoff scrubber	**Venturi scrubber +ESCS system**	Bag filter system +Venturi scrubber
Equipment configuration				
Dust content of outlet gas	< 5mg/Nm^3	< 5mg/Nm^3	**< 5mg/Nm^3**	< 5mg/Nm^3
Water consumption	1.2 L/Nm^3	1.5 L/Nm^3	**0.6 L/Nm^3**	0.4 L/Nm^3 *1
Pressure loss	4000mmaq	2500mmaq	**700mmaq**	250mmaq
Top gas pressure recovery	Base	+8%	**+15%**	+36%

*1 : For sludgy transportation

Reference list of VS-ESCS

BF	Start-up year	Remarks
Tobata 1BF	1985	
Kimitsu 3BF	1986	
Nagoya 3BF	2000	
Kimitsu 4BF	2003	

Reference list in NSC

Blast furnace	Top pressure MPa	Power generation KW
TOBATA No.1	0.28	16,300
TOBATA No.4	0.25	15,200
MURORAN No2	0.25	7,000
HIROHATA No.4	0.20	8,200
NAGOYA No.1	0.25	25,000
NAGOYA No.3	0.25	20,160
SAKAI No.2	0.18	8900
KIMITSU No2	0.23	20,000
KIMITSU No3	0.23	18,700
KIMITSU No4	0.24	18,900
OITA No.1	0.25	23,960
OITA No.2	0.30	27,900

Top pressure recovery technology

High efficient turbine itself
- Axial type + All stage variable stators

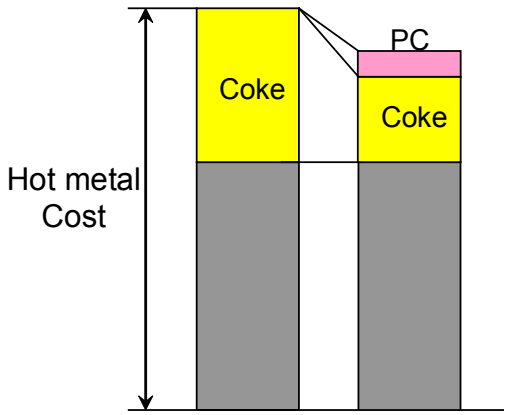
Optimized BF gas conditions at TRT inlet
- All BF gas introduce
- Combining low pressure-loss gas cleaning
  ⇨VS-ESCS

Abrasion resistance without gas deterioration
- No combustion of BF gas (= Wet type turbine)

3.1.2 Pulverized Coal Injection System

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Pulverized Coal Injection (PCI)



Introduction of PCI

⇩

Decrease of Coke rate

⇩

Cost reduction of Hot metal

Improving Cost Competitiveness

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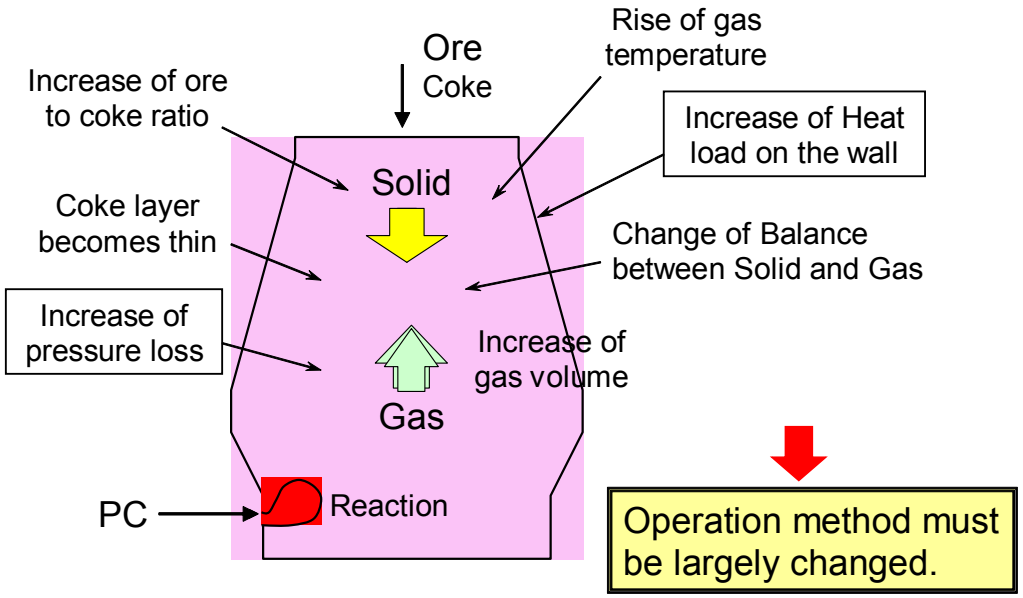
Possible Cost Savings after Upgrade

1. Cost Saving by Less Frequency of BF Relining
2. Cost Saving by Higher Productivity with Same BF
3. Cost Saving from Daily Operation

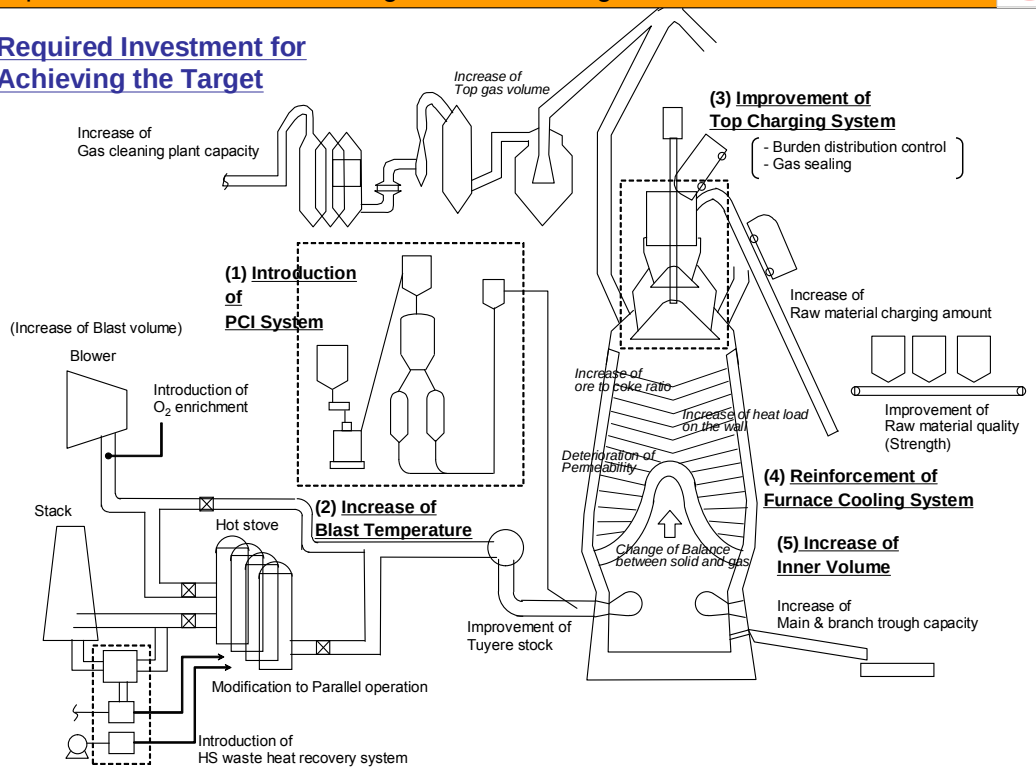
Item	Expected Effects	Economical Effects *
Pulverized Coal Injection (PCI) system	PC rate : 0 → 150 kg/t-hm Coke rate : 480 → 340 kg/t-hm COG rate : 32 → 0 Nm^3/t-hm	EUR 7.2 / t-hm
Top Gas Recovery Turbine (TRT)	Electric Power generation : 8,300 kW	EUR 1.7 / t-hm
Hot Stove Waste Heat Recovery system	COG saving : 6.5 Nm^3/t-hm	EUR 0.5 / t-hm
Hydraulic Taphole Opener system	Number of Taps : 15 → 8 times/day	EUR 0.6 / t-hm

* Assumption by using unit costs in Japan

Change of In-furnace Condition by introducing PCI



Required Investment for Achieving the Target



Conditions necessary for PCI operation

1) Proper Adjustment of Blast Conditions
2) Improvement of Raw Materials Quality
3) Proper Adjustment of Burden Distribution
4) Reinforcement of Furnace Cooling System



Advice in the BF operation.

PCI System

Advantages of the system

- Uniform Transfer of Pulverized Coal
- No Moving Part in Injection Equipment
- Natural Even Distribution to the Tuyeres



High Reliability & Easy Operation

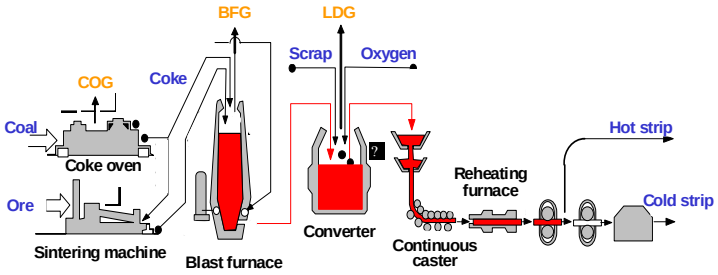
3.1.3 Blast Furnace Heat Recuperation

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1. BFG Preheating System

1.1 Sensible heat of Flue Gas in the Steel Industry

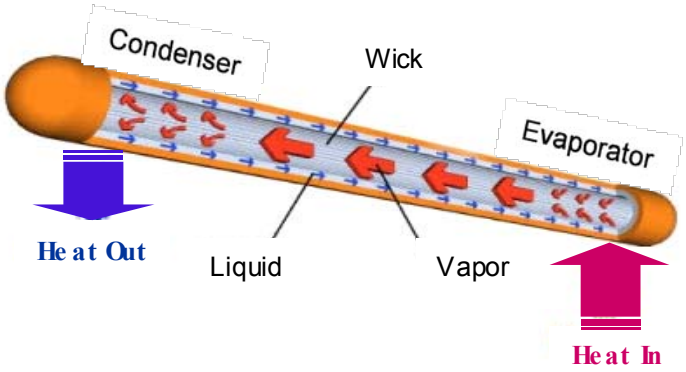
- The iron and steel making process diagram



- Sensible heat of Flue Gas in Reheating Furnace
  - Waste heats of High temperature grade (600 ~ 700 ?)
  - ➔ Exchange the Sensible heat of Hot air (300 ~ 400?)
- Sensible heat of Flue Gas in boiler of power plant
  - Wates heats of low and medium temperature grade (220 ~ 170?)
  - ➔ It's not easy to exchange heats due to the corrosion

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1.2 About Heat Pipe



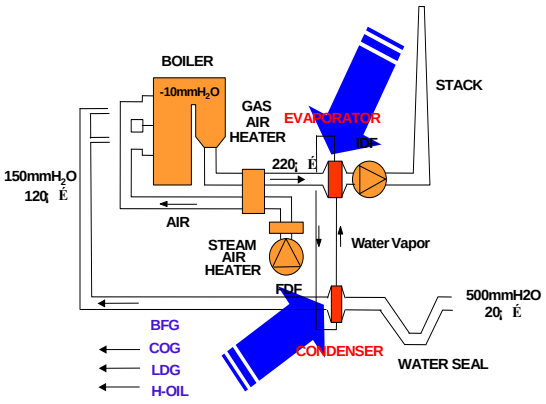


Merits of Heat Pipe

- No Power, No moving part
- Easy manufacturing (Wickless, carbon steel)
- Variable tube temperature

1.3 BFG Preheating System Description

BFG Preheating System



180~220℃ Temp. – sensible heat of flue gas
➔ 100~120℃ Temp. – sensible heat of BFG

Core Technology

- ❒ Anti-corrosion technology (SOx, NOx)
  - ***High surface temperature***
- ❒ Minimize pressure drop
  - ***Fin shape & tube arrangement***
- ❑ Closed loop thermosyphon System Design
  - ***Overall Heat Transfer Coefficient***
- ❑ Operating Technology

Test



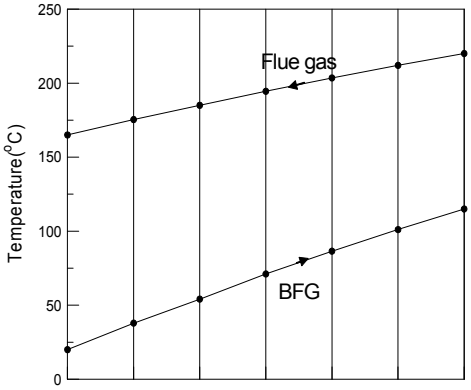
Heat Transfer Test



Corrosion Test

1.4 Thermal Design

- **Temperature distributions**

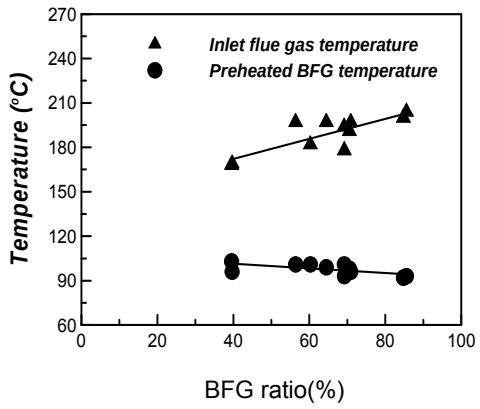


- **Specifications of the heat exchanger**

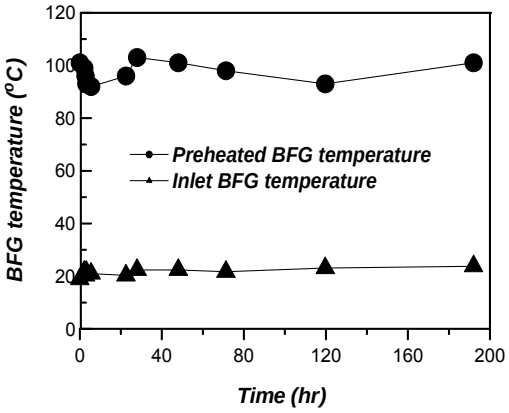
Item	Hot Fluid	Cold Fluid
Flow	Flue gas	BFG
Flow rate	59.9 kg/s	32.7 kg/s
Inlet Temp.	220	20
Outlet Temp.	165	126
Working Fluid	Boiler feed water	

1.5 Construction & Operation

Temperature variation of the flue gas and BFG



Variation of BFG temperature



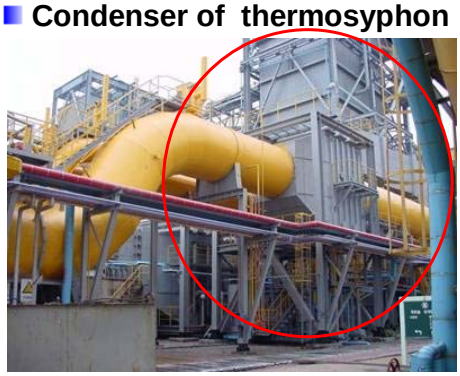
BFG flow rate: 48,600Nm³/hr ~ 111,400Nm³/hr

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Waste heat recovery system



Condenser of thermosyphon



Finned-tubes after 7months operation



There are no corrosion in heat exchanger.

1.6 Actual Results of the Application

Period	Actual Results	Memo
'95. 1 ~ '97. 5	(PW) #5 Boiler (1 Unit) POSCO R&D Project (RIST)	3,679 kWt/Unit
'98 ~ '00	(PW) #7,8,9,10 Boiler (4 Unit)	6,000 kWt/Unit
'05 ~ '06.9	(GW) # 1 ~ 9 (9 Unit)	9,000 kWt/Unit
~ 07. 12	(PW) #12 Boiler (1 Unit)	-
~08. 3	(PW) # 11 Boiler (1 Unit)	-

PW: Pohang Works
GW: Gwangyang Works

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Before





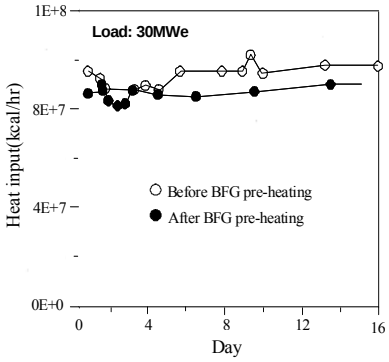
After



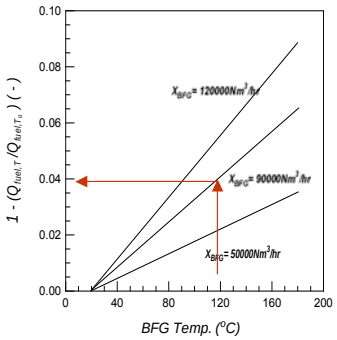


1.7 Energy Saving Effect

- Comparison of fuel energy input before/after BFG pre-heating system



- Calculated energy saving effect by the fuel gas pre-heating



- Averaged fuel saving effect after 7 months operation

BFG pre-heating temperature	104°C
Ratio of thermal efficiency increase	3.3%
Reduced fuel heat input per kWh	102kcal/kWh

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1.8 Conclusion Remarks

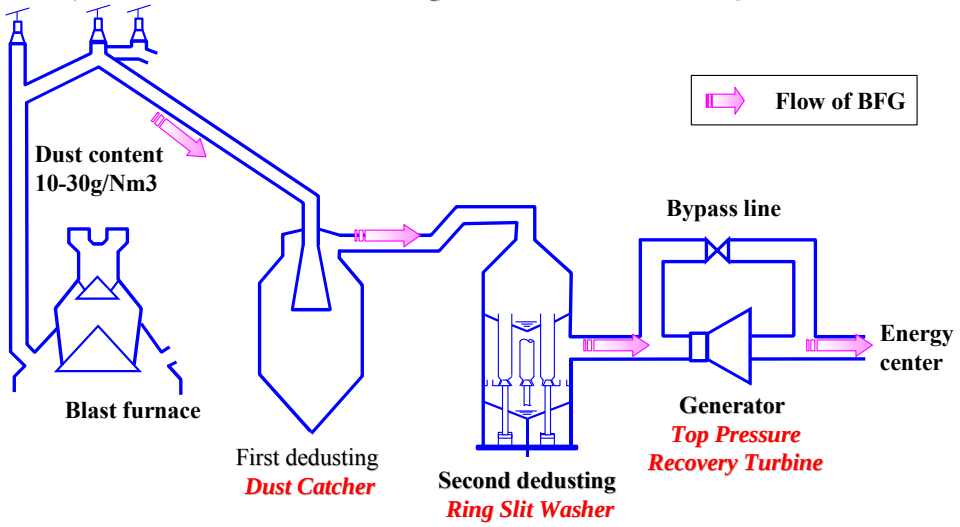
- Loop thermosyphon is the most economic device for recovering waste heats of low and medium temperature grade in the steel industry.
- For the case of the boiler, 3~5% of energy saving has been achieved and the payback period was within 1.5 years.
- Its reliability as well as its stability have been proved through its more than 10 years of operation.

3.1.5 Blast Furnace Gas and Cast House Dedusting

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BFG Dedusting

1) Dedusting device flow
(No.1 Blast Furnace at Kakogawa Works, Kobe Steel)

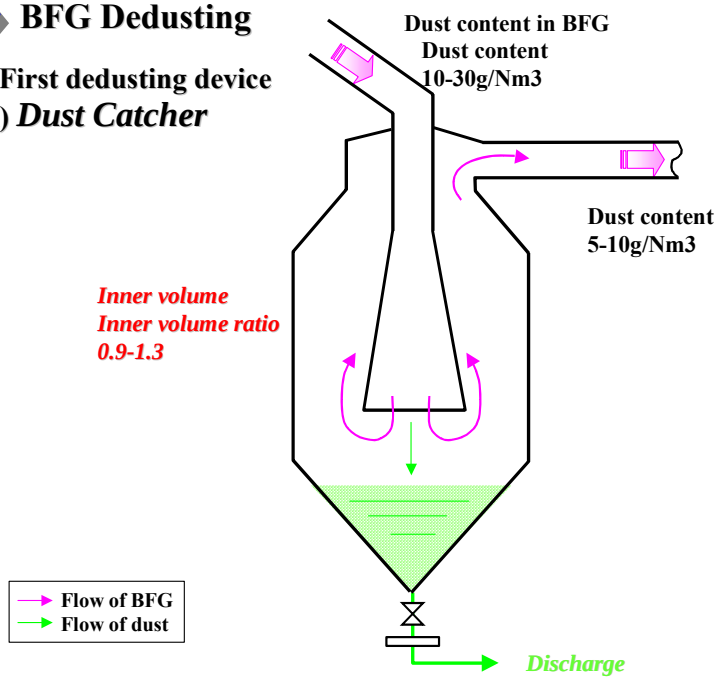


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BFG Dedusting

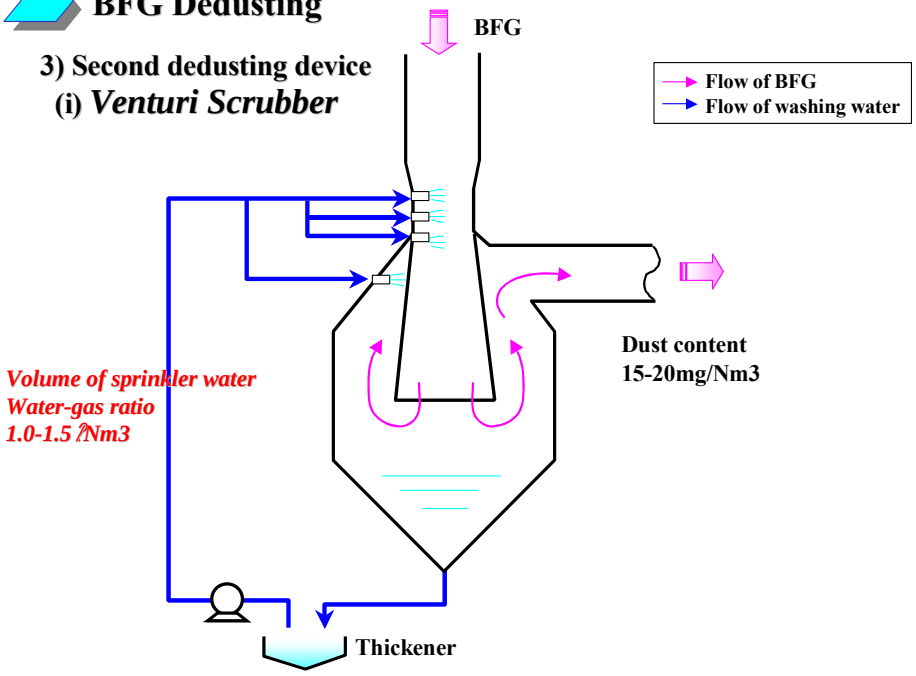
2) First dedusting device
(i) *Dust Catcher*



4

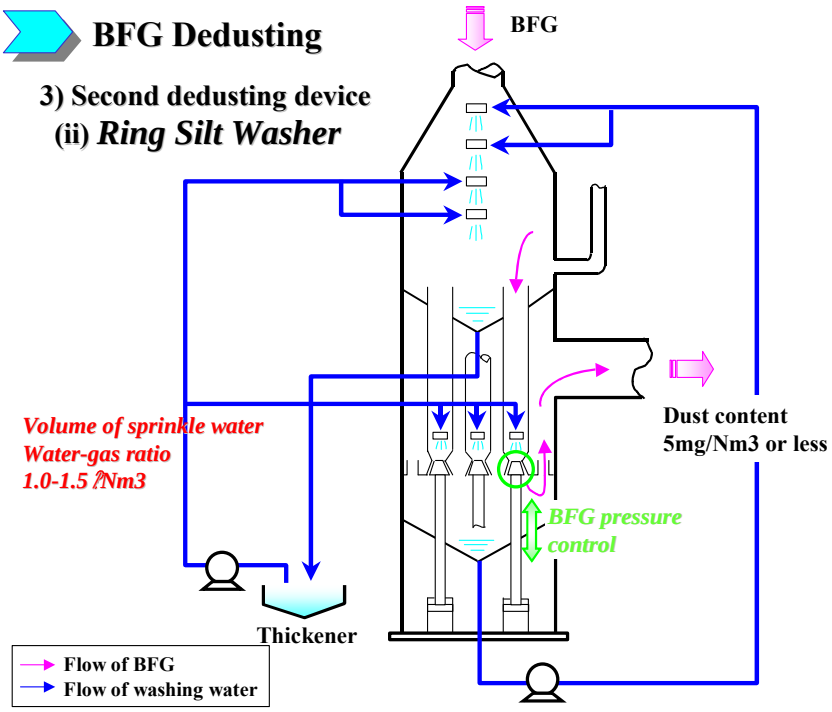
BFG Dedusting

3) Second dedusting device
(i) *Venturi Scrubber*



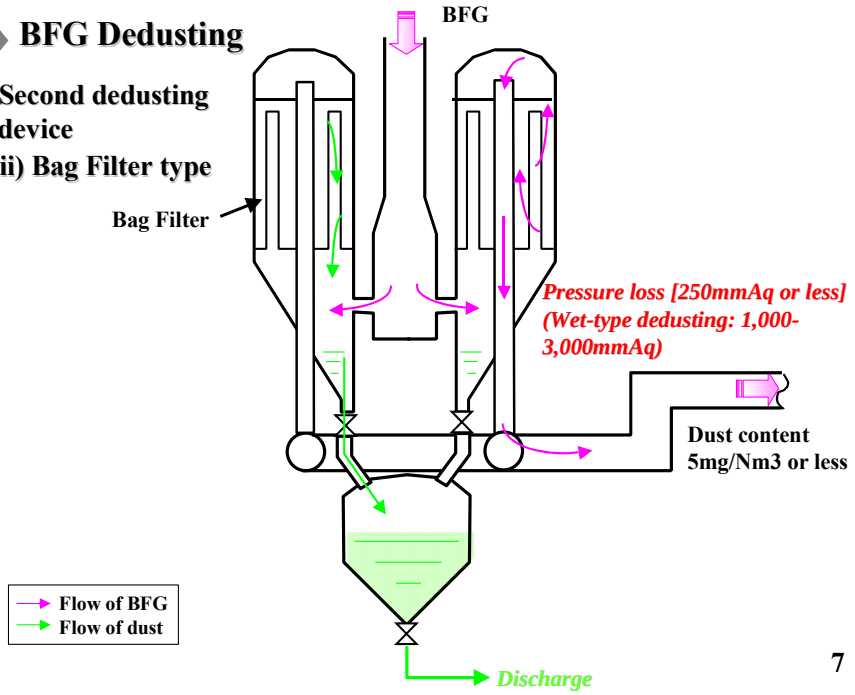
BFG Dedusting

3) Second dedusting device
(ii) *Ring Silt Washer*



BFG Dedusting

3) Second dedusting device
(iii) Bag Filter type



7

BFG Dedusting

4) Characteristics of dedusting devices

First dedusting	*Dust Catcher*	*Dust Catcher*	*Dust Catcher*
Second dedusting	Wet-type dedusting *Venturi Scrubber*	Wet-type dedusting *Ring Slit Washer*	Dry-type dedusting *Bag Filter*
Ability to remove dust	*15-20mg/Nm3*	*5mg/Nm3 or less*	*5mg/Nm3 or less*
Pressure control	Not available	Available	Not available
	1. EP and VS are necessary for the VS outlet to cover the ability to remove dust. 2. Pressure control devices (septum valve) and noise control devices (silencer) are necessary. ⇩ VS with pressure control or high-performance EP is available.	1. Devices to remove dust such as EP are not necessary. 2. Pressure control devices (septum valve) and noise control devices (silencer) are not necessary.	1. Devices to remove dust such as EP are not necessary. 2. Pressure control devices (septum valve) and noise control devices (silencer) are necessary. 3. Water treatment devices are not necessary. 4. More electricity can be recovered by TRT.

8

BFG Dedusting

5) Installation status in Japan

First dedusting	***DC***	***DC***	***DC***	***DC***
Second dedusting	***VS***	***RSW***	***Bag Filter***	**Combination of VS/RSW and Bag Filter type**
Number of furnaces with BFG dedusting devices	**16/28**	**6/28**	**2/28**	**4/28**

DC Dust Catcher
VS Venturi Scrubber
RSW Ring Slit Washer

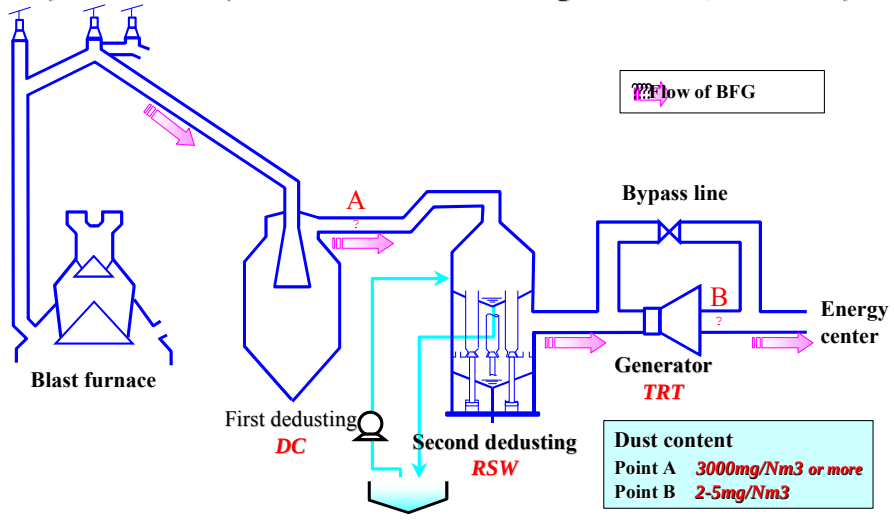
Wet-type dedusting devices (VS/RSW) are mainly used for BFG dedusting.

Some furnaces employ the combination of the wet type and the dry type.

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BFG Dedusting

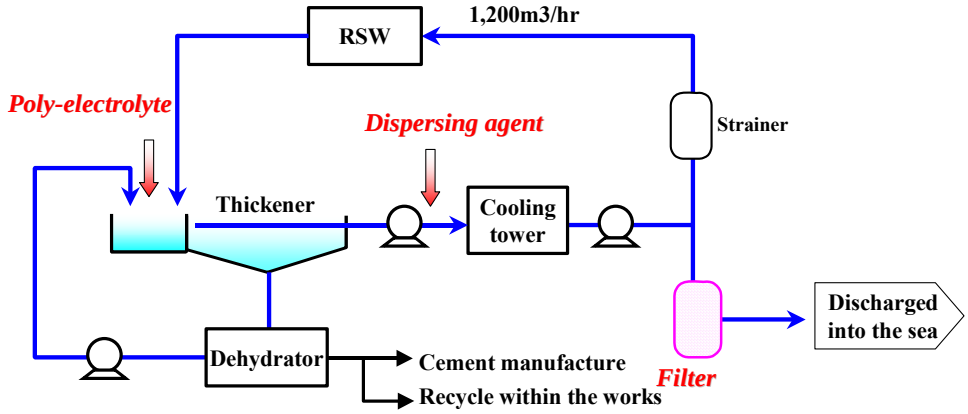
6) Dust content (No.1 Blast Furnace at Kakogawa Works, Kobe Steel)



10

BFG Dedusting

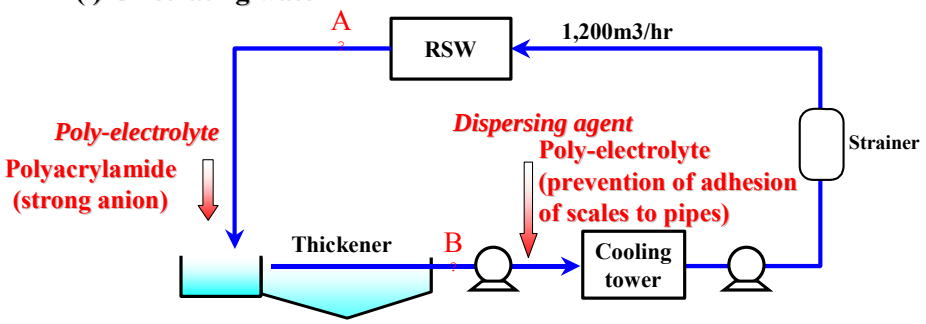
7) Water treatment: Device flow
(No.1 Blast Furnace at Kakogawa Works, Kobe Steel)



11

BFG Dedusting

8) Water quality control
(i) Circulating water



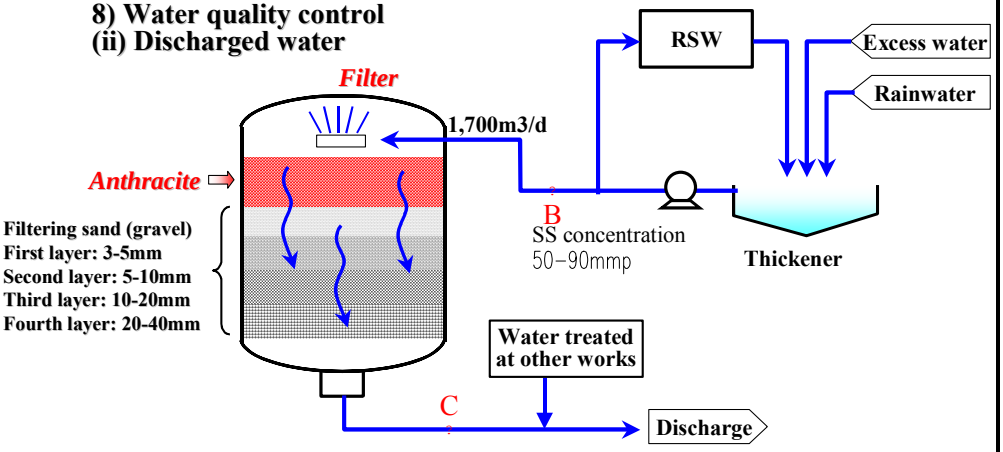
Circulating water: Point A/Point B

	Water discharged by RSW: Point A	Water treated by the thickener: Point B
	SS concentration	SS concentration
Control value		100ppm
Actual value	1,200 - 1,900ppm	50 - 90ppm

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BFG Dedusting

8) Water quality control
(ii) Discharged water



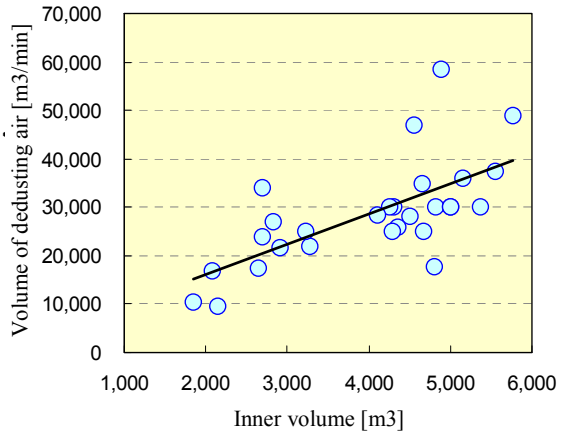
Discharged water: Point C

	PH	COD (ppm)	SS (ppm)	N-Hex (ppm)	Sol-Fe (ppm)
Control value	5.8-8.6	?	20	1	1
Actual value	8.5	14.9	6	?1	0.37

COD is controlled at 5 ppm for total discharged water.

Cast House Dedusting

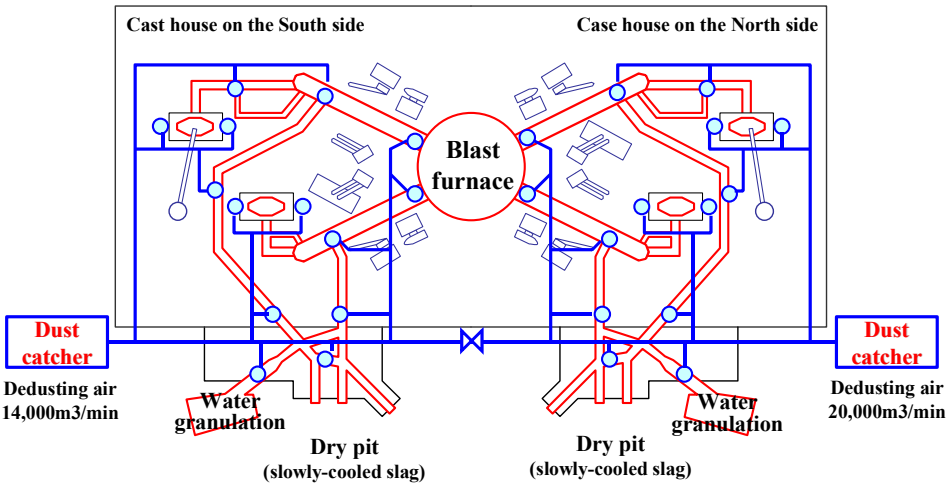
1) Relationship between the inner volume and the volume of dedusting air



The volume of dedusting air increases as blast furnaces become larger.

Cast House Dedusting

2) Dedusting points (No.1 Blast Furnace at Kakogawa Works, Kobe Steel)

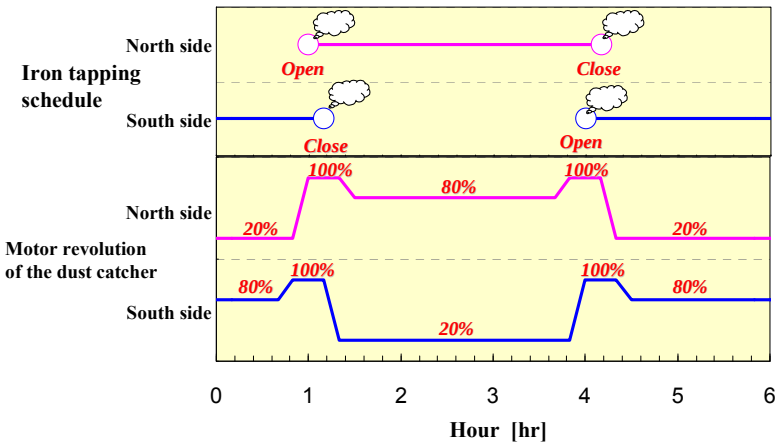


Dedusting points: Tapping hole, skimmer, metal runner, concentrate runner, slag runner

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Cast House Dedusting

3) Efficient operation

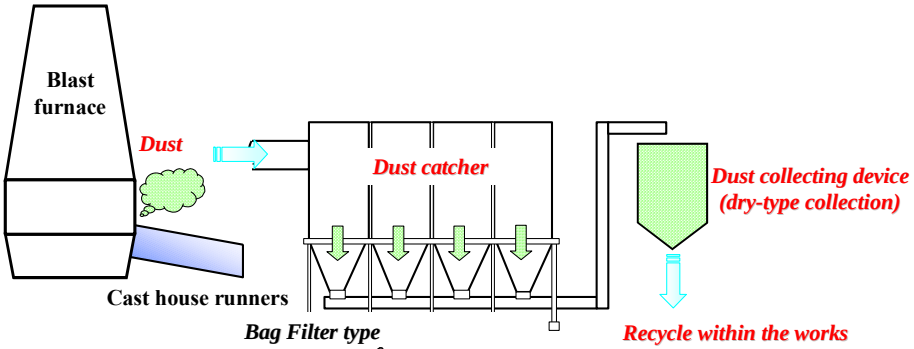


The volume of dedusting air is controlled depending on the timing of iron tapping (dust generation).

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Cast House Dedusting

4) Cast house dedusting device flow
(No.1 Blast Furnace at Kakogawa Works, Kobe Steel)



Bag Filter type
Dedusting air 20,000m3/min
14,000m/min ?

Dust collection 3.0-3.5kg/tp

T.Fe	FeO	SiO2	CaO	S
58.6%	5.8%	1.8%	8.3%	0.13%

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Conclusion

BFG Dedusting

- Dust catchers and wet-type dedusting devices are mainly used for first dedusting and second dedusting, respectively.
- Dust can be reduced to 2-5 mg/Nm3 at the TRT outlet
- Circulating water is used for washing. Water quality is controlled by filtering upon discharge.

Cast house dedusting

- The volume of dedusting air is controlled depending on the inner volume.
- Dedusting can be operated depending on the points where dust is generated and the timing of iron tapping.
- Collected dust is effectively used within the works.

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Blast Furnace Gas Cleaning Technology

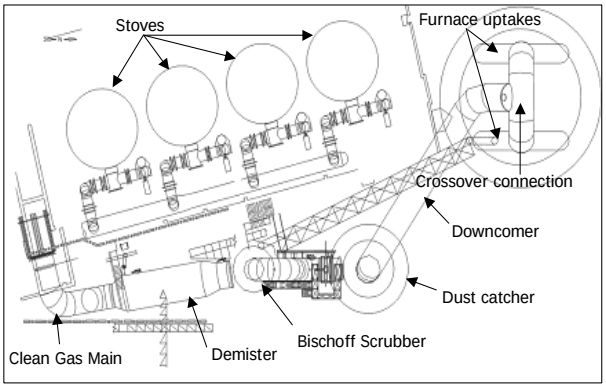
Dust Removal and Cast House Dust Control

Dust removal includes:

- *Dry large particulate removal*
- *Wet fine particulate removal*
- *Clean gas used to heat stoves or produce power*

Cast house dust control includes:

- *Atmosphere pulled through baghouse*
- *Clean gas exhausted to atmosphere*



Plan view of Gas Cleaning System



Blast Furnace Gas Flow Path

Gas flow out of the furnace

- After the gas exits the burden, it flows upward through the four furnace uptakes to the crossover connection and to the downcomer duct.
- Gas flow is initially upward to minimize particle entrainment.

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Blast Furnace Gas Flow Path

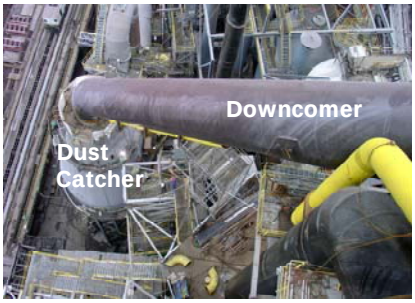
Gas flow from furnace to dust catcher

- Crossover connection recombines gases and directs them towards dust catcher through the downcomer.

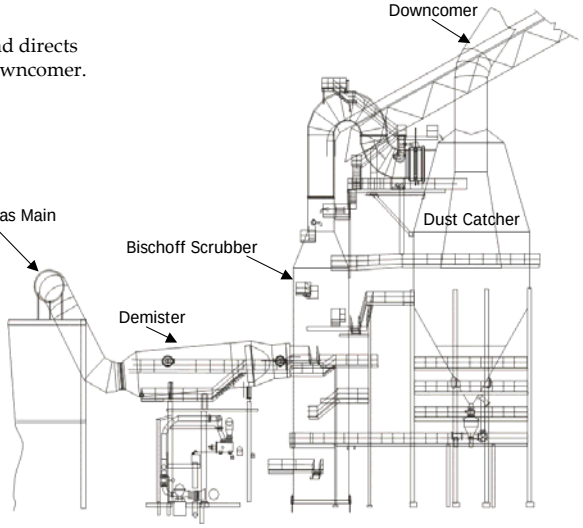


- Crossover section provides area to mount bleeder valves. Bleeder valves release excess gas pressure when necessary.

Dirty gas bleeder valve



Downcomer to Dust Catcher



Elevation view of Gas Cleaning System

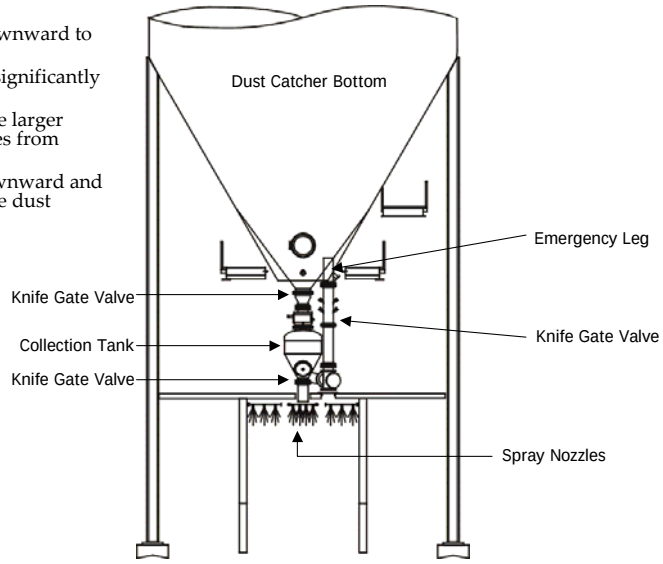
Dust Catcher

Dust Catcher Details

- Gas flow is changed from downward to upward direction.
- Gas velocity is also reduced significantly as flow area is increased.
- Downward momentum of the larger particles prevents the particles from following the gas stream.
- Larger particles continue downward and are collected in the base of the dust catcher.

Dust Catcher Dumping

- Double knife gate valve arrangement allows solids removal without pressure loss.
- Water sprays positioned over discharge cool the solids and prevent fires.



Dust Catcher dumping mechanism

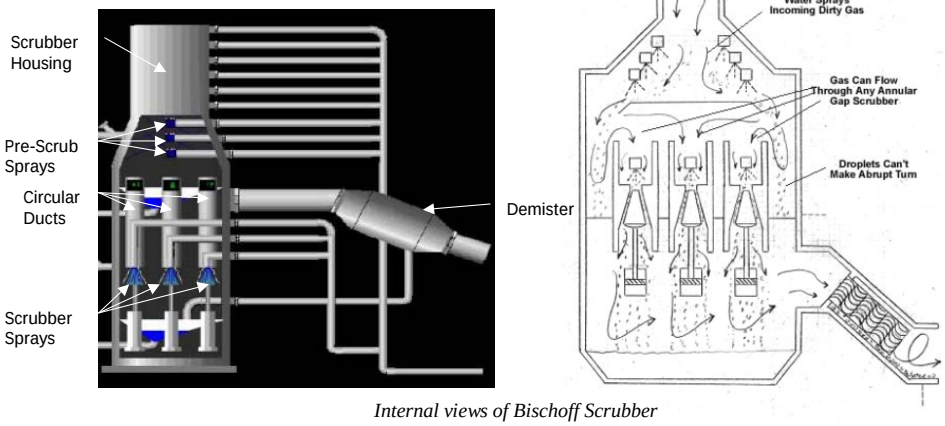
Bischoff Scrubber

Bischoff Scrubber Details

- Wet Scrubber in which the smaller particles are absorbed into water stream
- High pressure drop forces water droplets to collide with particulate matter
- The heavier water/particulate drops fall out of the gas stream – liquid is collected in the base of the scrubber

Bischoff Scrubber Water Treatment

- Additives are used to enhance particulate agglomeration
- Solids are removed by filter press
- Make-up water is needed to replace evaporation losses
- Zero liquid blow down



Internal views of Bischoff Scrubber

Horizontal Demister

Horizontal Demister Details

- Purpose is to remove entrained water droplets from the gas stream.
- Demister Internals (Spine Vanes) are designed to force droplets to impinge solid surfaces and drain out of the demister. The concept is similar to that used in the Dust Catcher.
- Recovered water is returned to the Scrubber.

Uses of Blast Furnace Gas energy content

- Preheat blast air to Blast Furnace Stoves
- Power generation in plant boiler
- Flared during upset conditions

Clean Gas Main



Clean Gas Main

Clean Gas Main Details

- Duct that distributes clean blast furnace gas to stoves of boiler house
- Connection for blast furnace gas enrichment
- Outlet to flare stack

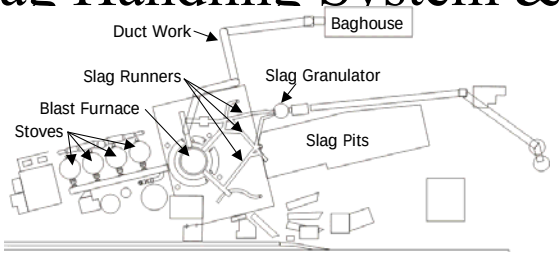


Flare stack

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3.1.7 Cast House Dust Suppression

Slag Handling System & Baghouse

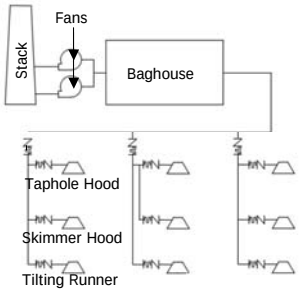


Cast House Dust Suppression System



Cast House Dust Suppression System

- Molten iron and slag emit smoke and heat while flowing from taphole to ladle or slag granulator to pit.
- Dust Suppression System designed to contain emissions.
- "Dirty" air drawn through baghouse and exhausted to atmosphere.
- Dust Suppression System has multiple collection hoods
  - Overhead hoods above each taphole and above each skimmer
  - Below-floor collection hoods above each tilting spout



Cast House Dust Suppression System

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Cast House Dust Suppression Baghouse

Cast House Dust Suppression Baghouse Details

- Baghouse contains separate collection chambers.
- Each collection chamber has a suction fan.
- Individual chambers may be shut down without affecting operation.
- Dust passes through rotary dump valves, covered screw flights, and into covered bins.



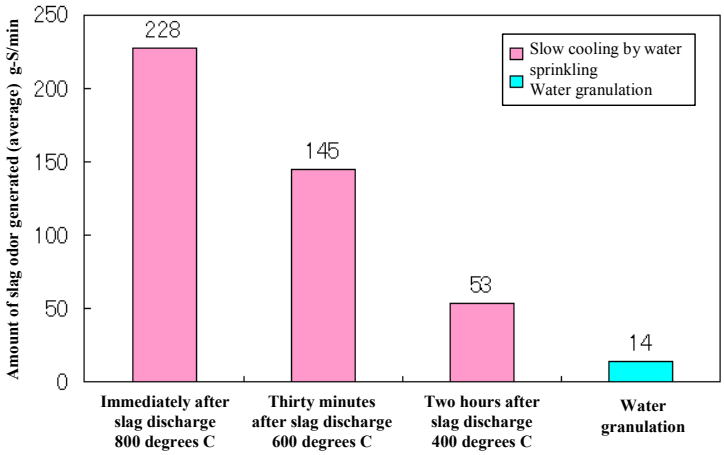
Cast House Dust Suppression Baghouse

3.1.7 Slag Odor Control

Japan - Best Available Technologies for Ironmaking

Other Environmental Measures

1) Slag odor control

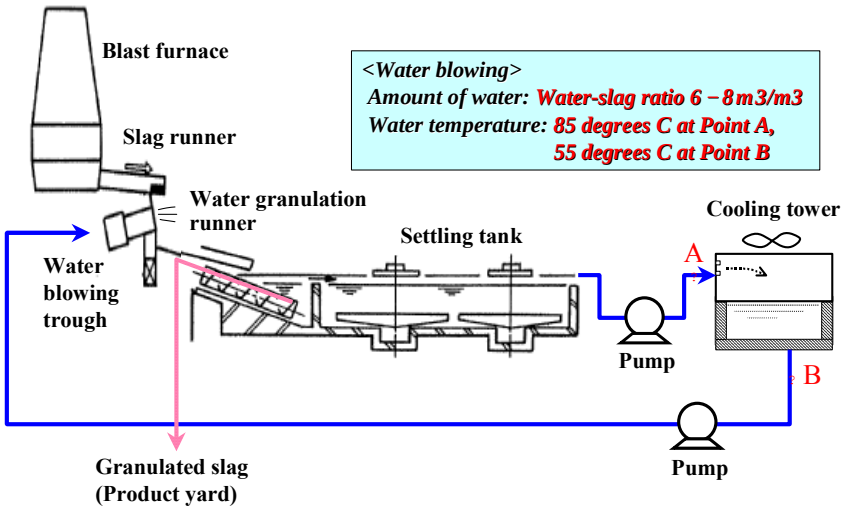


Slag odor can be reduced significantly by water granulation.

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Other Environmental Measures

2) Water granulation device flow
(No.1 Blast Furnace at Kakogawa Works, Kobe Steel)



<Water blowing>
Amount of water: Water-slag ratio 6 – 8 m3/m3
Water temperature: 85 degrees C at Point A,
55 degrees C at Point B

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Conclusion

Other environmental measures

- Water granulation of slag is effective in preventing slag odor.

- Circulating water is used for blowing (cooling tower is installed).

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3.3.1 Smelting Reduction Processes

Australia - Best Available Technologies for Ironmaking

HIsmelt®

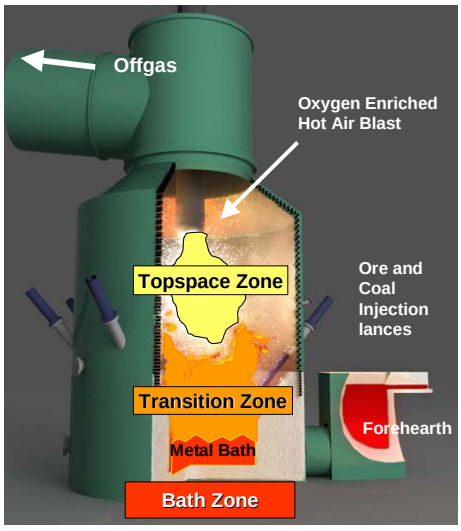
- HIsmelt® is a direct smelting technology which:
  - smelts iron ore fines and
  - non coking coal,
  - to produce a premium grade iron.
- The HIsmelt Technology:
  - Is a potential replacement for the blast furnace or a new source of low cost iron units for the electric arc steelmaking industry.
  - Commercial viability will be demonstrated by the 0.8Mtpa plant in operation at Kwinana, Western Australia.
  - HIsmelt is positioned to become a technology of choice for future ironmaking requirements





Australia - Best Available Technologies for Ironmaking

HIsmelt®: An innovative direct smelting technology



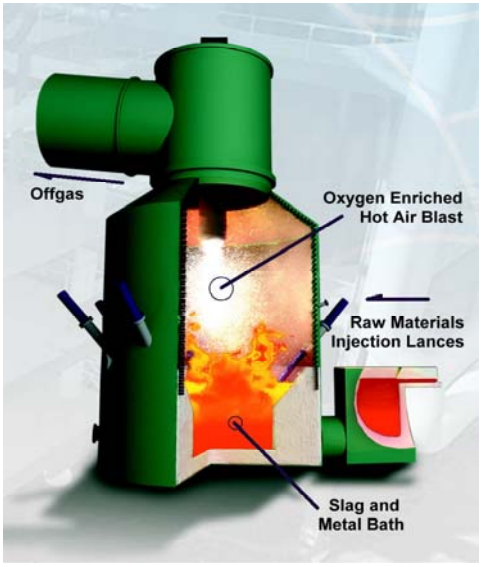
The three zones within the Smelt Reduction Vessel

Reaction gas (CO) and coal volatiles are combusted with an oxygen enriched Hot Air Blast, generating heat.

Transfer of heat from combustion of CO from the topspace zone to the bath zone sustains reduction reactions. Slag splashing protects water-cooled panels.

Ore reduces when it contacts carbon in the metal, producing CO gas. Carbon from the coal dissolves in the bath to replace the carbon in the metal. Coal ash and ore gangue are fluxed to slag. Reactions are contained in a small refractory lined hearth.
Metal is tapped continuously through a forehearth.

HIsmelt®: A simple and flexible process



- **Ore & coal is injected into the melt**
  - Coal dissolves in molten iron bath
  - Ore smelts rapidly, consumes heat
  - Violent CO gas evolution produces a splash
- **Hot blast is injected in the topspace**
  - CO burned to CO_2
  - Heat transfers to droplets that return to bath
  - A fireball is centrally contained
  - Slag splashes water cooled panels and insulates
- **Metal flows out, slag is batch-tapped**
  - Contains a forehearth similar to a mini-BF
  - Slag is batch tapped through water cooled notch
- **A key feature is deep injection of solids**
  - Excellent fines capture
  - Stronger mixing
  - Higher heat-to-bath rates

Australia - Best Available Technologies for Ironmaking

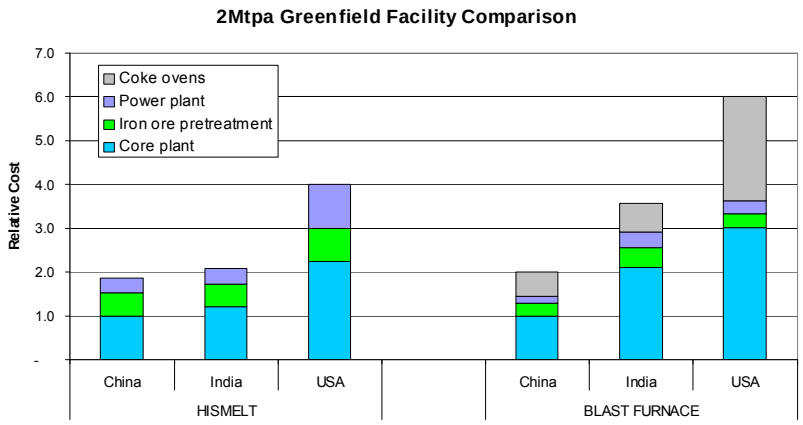
The HIsmelt® Advantage

- **Greater Flexibility**
  - Wide range of raw materials
  - Flexible output and operation
- **Low Capital Costs**
  - No coke ovens, sinter plants, blending yards
  - Known support equipment
- **Low Operating Costs**
  - Utilises low cost raw materials (iron ore fines, non-coking coals)
  - Single source feeds
- **Low Environmental Impact**
  - No production of dioxins, furans, tars and phenols
  - Reduced CO_2, SO_2 and NO_x
  - Can utilise steel-plant wastes
- **High Quality Iron Product**
  - Impurities report to the slag (i.e. Si, P) – not the metal





Lower Capital Cost:
Compared to Greenfield Expansions



Basis: 2006

Ausmelt Ausiron® Technology

Bath smelting iron production for the supply of high-quality hot metal and pig iron for use by both integrated and EAF-based steel producers. Ausmelt offers facilities that benefit steel producers through the use of low-cost feed materials, and recycling of steel plant by-products.





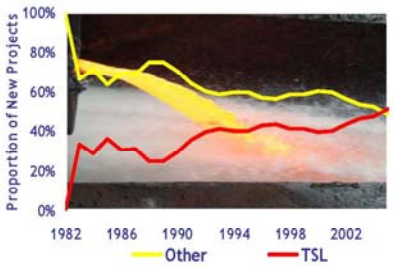
- **Adapted from a widely-used bath smelting process**
  robust technology platform
- **Direct use of iron ore fines / steel plant dusts**
  no sintering, pelletizing, or complex feed arrangements
  tolerates phosphorus, zinc, and alkalis in feed
  can use BOF/BF dust, millscale, EAF dust, mine tailings
- **Direct use of thermal coals**
  reduced coal supply costs; no coke oven operations
- **Single furnace with direct waste energy recovery**
  low installation costs; simple plant flow sheet
- **Low-pressure (induced draught) operation**
  easy to start & stop; flexible operations,
  simple maintenance; inhibits fugitive emissions
- **Environmentally robust iron production**
  contributes no coke-oven or sinter plant emissions
  allows recycling of steel plant dusts and slags
  makes effective use of coal energy

AUSMELT GLOBAL ENVIROMETAL TECHNOLOGIES AUSIRON®

Ausmelt Bath Smelting Experience

Ausmelt's Top Submerged Lance (TSL) smelting technology is commercially used in the production of a wide range of non-ferrous metals. Its success is driven by high intensity, and therefore low-cost smelting together with demonstrated environmental advantages. The adaptation of TSL smelting for iron production has been successfully proven at a purpose-built Ausiron® demonstration facility.

Adoption of TSL by Non-Ferrous Industries



Ausmelt TSL Projects (since 2002)

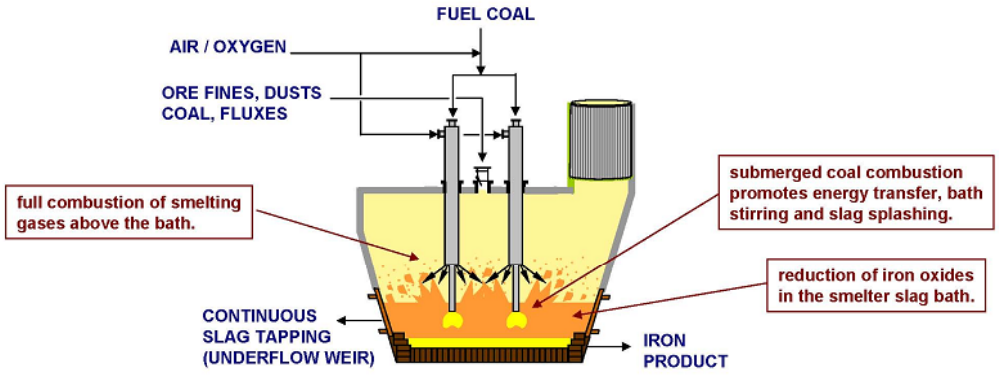
Client	Location	Product	AP6
Yunnan Tin Corporation	Gejiu City, China	Pb bullion	✓
Huludao Copper Group	Huludao, China	Cu matte	✓
Chifeng Jinjian Copper Group	Chifeng, Inner Mongolia, China	Cu matte	✓
Korea Zinc (2 TSL furnaces)	Onsan, South Korea	Zn fume	✓
Jilin Nickel Group	Jilin Province, China	Ni matte	✓
Jinchuan Nonferrous Metals Corp.	Gansu Province, China	Ni matte	✓
Dowa Mining Co. Ltd.	Akita, Japan	Blister Copper	✓
Young Poong Corp.	Sukpo, South Korea	Zinc fume	✓
Russian Copper Co.	Chelyabinsk, Russia	Cu matte	×
Hindustan Zinc Limited	Chanderiya, India	Pb bullion	✓
Korea Zinc	Onsan, South Korea	Cu matte	✓
MAPO Project	Seoul, South Korea	Metal oxide fume	✓
Birla Copper (2 TSL furnaces)	Dahej, India	Blister Cu	✓
Anhui Tongdu Copper	Tongling City, China	Cu matte	✓
Amplats (2 furnaces)	Rustenburg, South Africa	Ni/Cu matte	×
Yunnan Tin Corporation	Gejiu City, China	Sn metal	✓

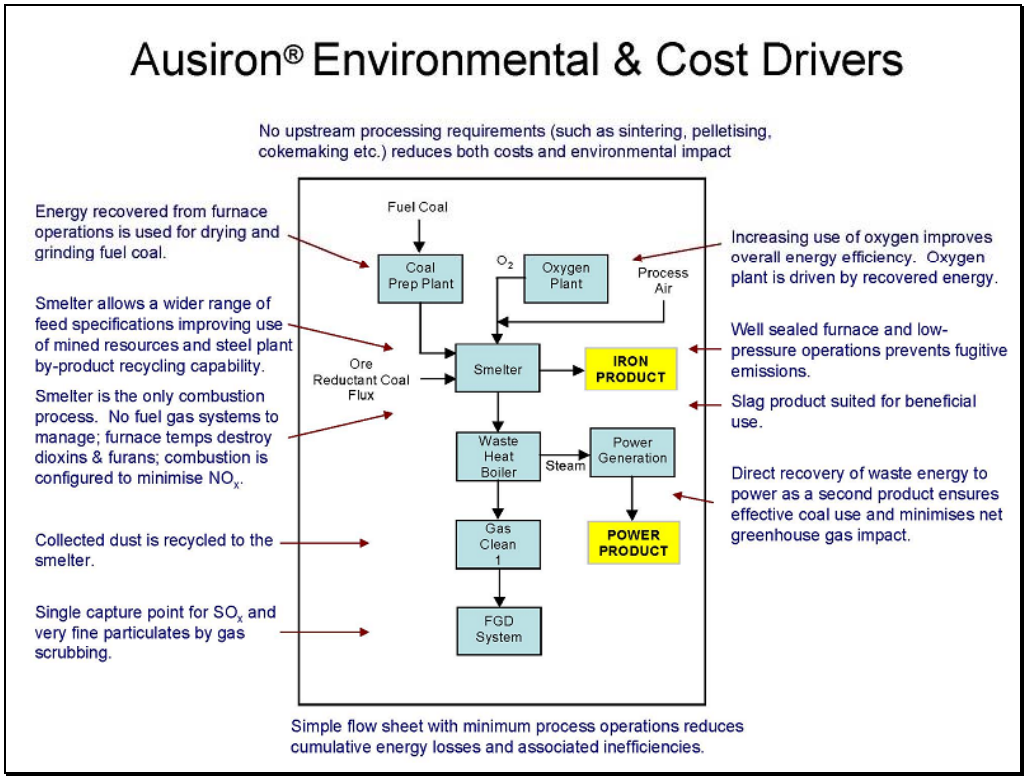
Ausiron® Process Operation

Ferrous materials, fluxes and raw coal are metered from storage on to a common feed conveyor and delivered directly to the furnace. Controlled water addition via an in-line mixer ensures process capture of fine particles.

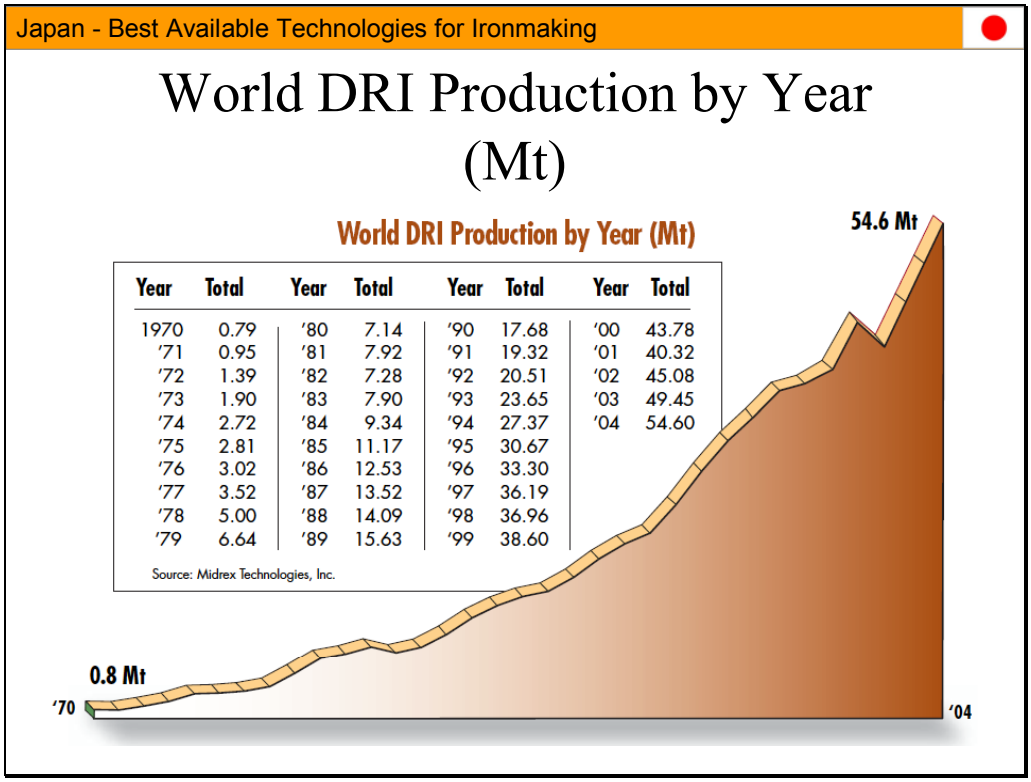
Smelting occurs in the upper region of the furnace slag bath. Process energy is supplied by the submerged combustion of fine coal at the lance tips, and from the complete combustion of smelting product gases above the bath. The proven "TSL" process configuration achieves high smelting rates, and enhanced control of smelting conditions.

Lances and furnace walls (excluding the iron bath zone) are force-cooled to freeze a protective slag coating that also minimises process heat losses. Boiler-tube cooling is used above the bath zone, and the furnace waste gases pass directly to a waste heat boiler to maximise energy recovery.



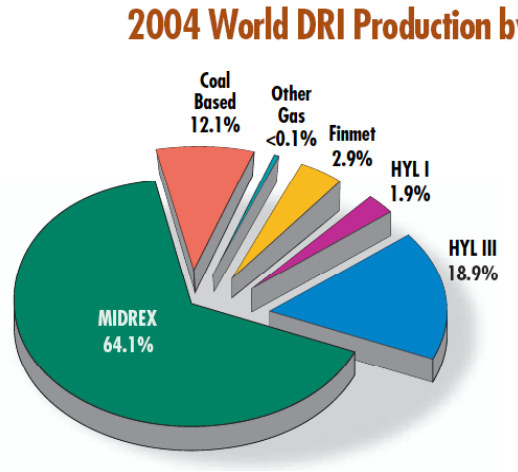


3.3.2 Direct Reduction Processes



Year	Total	Year	Total	Year	Total	Year	Total
1970	0.79	'80	7.14	'90	17.68	'00	43.78
'71	0.95	'81	7.92	'91	19.32	'01	40.32
'72	1.39	'82	7.28	'92	20.51	'02	45.08
'73	1.90	'83	7.90	'93	23.65	'03	49.45
'74	2.72	'84	9.34	'94	27.37	'04	54.60
'75	2.81	'85	11.17	'95	30.67		
'76	3.02	'86	12.53	'96	33.30		
'77	3.52	'87	13.52	'97	36.19		
'78	5.00	'88	14.09	'98	36.96		
'79	6.64	'89	15.63	'99	38.60		

World DRI Production by Process



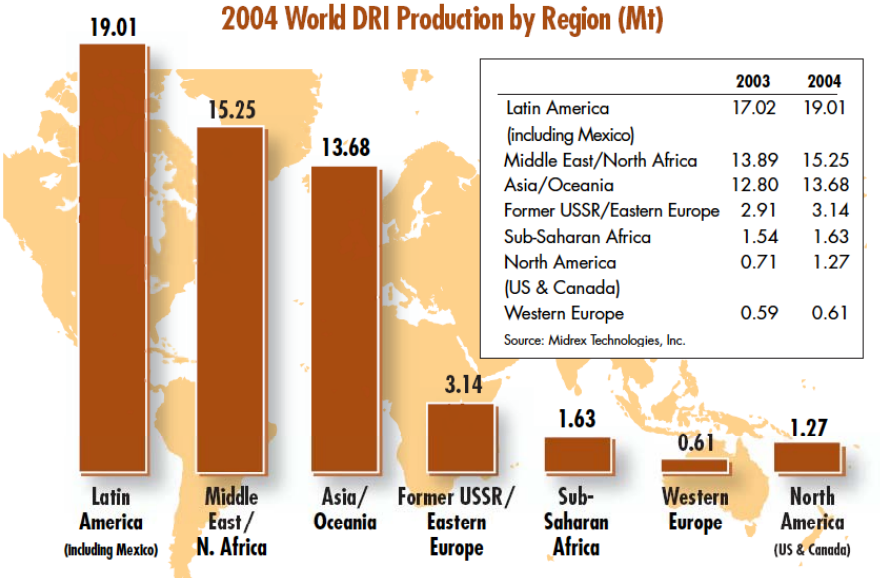
Total World Production 54.6 Mt

	2003	2004
Midrex	64.6%	64.1%
HYL III	18.4	18.9
HYL I	1.3	1.9
Finmet	5.2	2.9
Coal Based	10.2	12.1
Other Gas	0.4	<0.1

Source: Midrex Technologies, Inc.

Japan - Best Available Technologies for Ironmaking

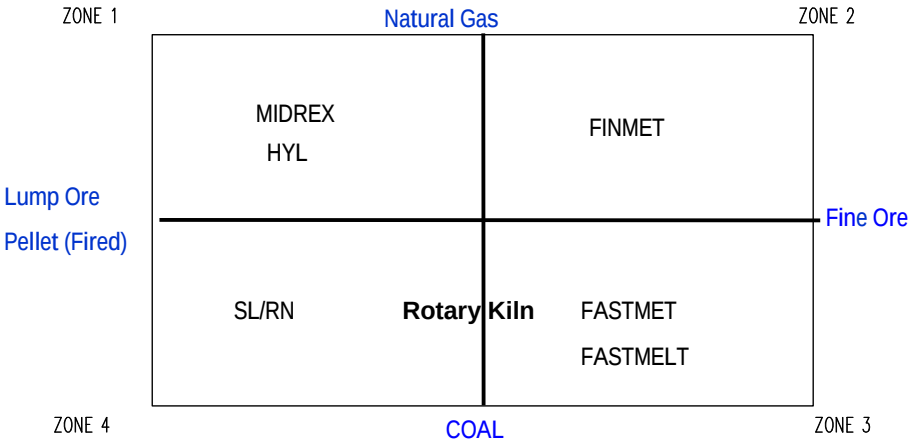
World DRI Production by Region (Mt)



	2003	2004
Latin America (including Mexico)	17.02	19.01
Middle East/North Africa	13.89	15.25
Asia/Oceania	12.80	13.68
Former USSR/Eastern Europe	2.91	3.14
Sub-Saharan Africa	1.54	1.63
North America (US & Canada)	0.71	1.27
Western Europe	0.59	0.61

Source: Midrex Technologies, Inc.

Categorization of Direct Reduction Technologies



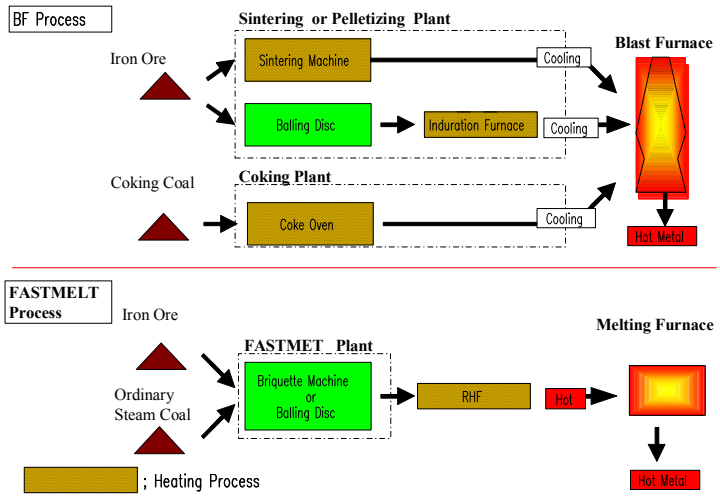
Energy Conservation and Environmental Protection Effect of DRI Production

Type	Product	Energy conservation, environmental protection effect
Based on natural gas (MIDREX process)	**Reduced iron**	*** Coke, which causes a high environmental burden, is not necessary** *** The reductant is natural gas (clean energy)** **(CH4+2O2 → CO2+2H2O)**
Coal-based (FASTMELT process)	**Reduced iron or hot metal**	*** Coke, which causes a high environmental burden, is not necessary** *** Sintered ore, fired pellets are not necessary** *** Energy can be reused within the process system**

DRI production process are treated as important promoted technologies also in China.

"Newly Created Item as a National Focus Technology", "Orientation for Metallurgy Development for "10/5" time period"

Comparison between BF and FASTMELT



FASTMELT process has less heating process as well as less equipment.

That is why FASTMELT process is high energy efficiency and low investment cost.

Application of Direct Reduction Processes in China

* Requirements in terms of iron works
- Since China has an extensive inland area, it needs small-scale iron works located in the markets ("market mills") same as in the US.

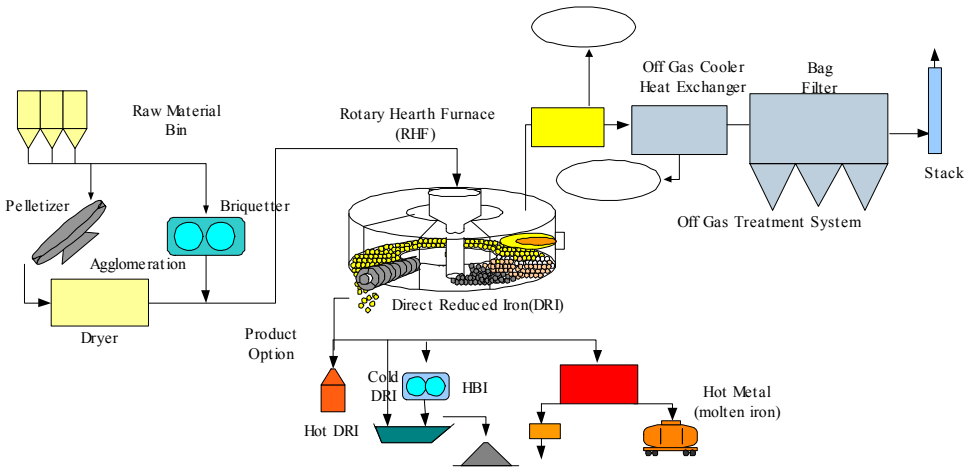
* Requirements in terms of raw material and fuel
- Since there is a lack of scrap and electric power, the market mill model of the US, which is based on electric furnaces, cannot be applied.
- The resources of natural gas are limited.
- China has rich resources of coal.

Direct Reduction process which is based on a relatively small scale and based on coal is a suitable solution.

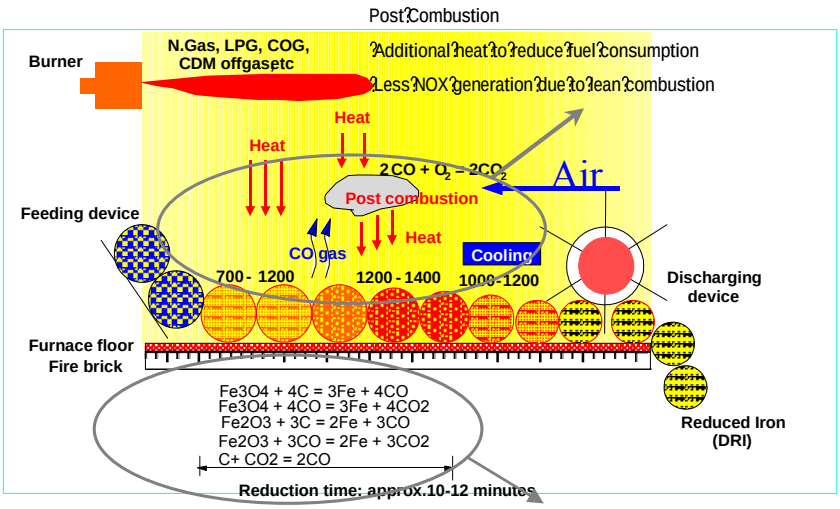
Characteristics of the FASTMET Process

- **Pre-treatment of raw material is not necessary**
  - **There is no need for process of sintering nor firing.**
  - **Direct use of non-coking coal, not coke.**
- **The energy efficiency is high.**
  - **Fuel usage can be reduced because a secondary combustion of close to 100% is achieved in the rotary hearth furnace.**
  - **By-product energy is completely reused within the system**
- **Environmentally friendly with low emissions**
  - **Emissions of SOx, NOx, dioxin, CO2 are low**

FASTMET Process Flow



Mechanism of Reduction



Intimate contact of oxide and carbon

Higher rate of reduction reaction

Lower starting Temperature of gasification

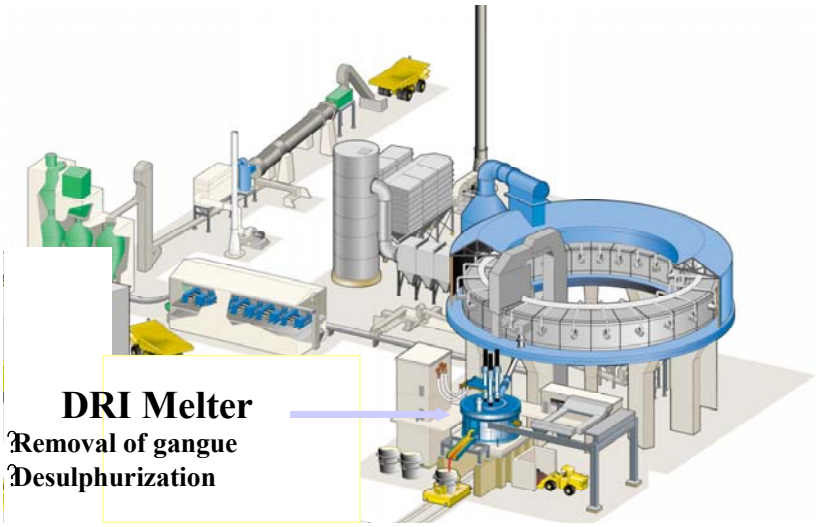
Iron Ore and Coal for FASTMET

		Tolerable	Preferable
Iron ore	Total Fe	60%	65%
	Particle size	3 mm >	44μ >70%
Coal	Volatile matter	42%	26%
	Ash	16%	10%

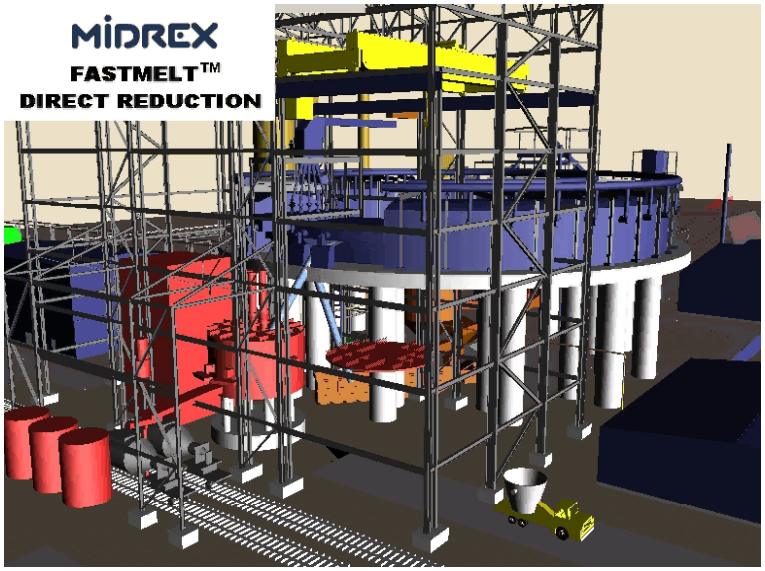
FASTMET/Midrex DRI Chemistry

Items	FASTMET	Midrex
Metallization	90.0	92.0
Total Fe	86.9	92.7
Metallic Fe	78.2	85.3
Carbon	4.0	1.1
Sulfur	0.15	0.01
Gangue	6.35	3.60
Total	100.0	100.0

FASTMELT Plant



FASTMELT 3D



Typical FASTMELT Hot Metal Chemistry

Temperature	Fe	C	Si	S	P
1,450-1,550 deg.C	95.5-98%	2.0-4.5%	0.1-0.6%	<0.05%	<0.04%

Commercial Plants by FASTMET

The records

- Nippon Steel HIROHATA (190,000 t/y Steelmaking dust
- KOBE Steel KAKOGAWA (14,000 t/y BF,BOF,EAF dust

Nippon Steel HIROHATA



KOBE Steel KAKOGAWA



Energy Efficiency of the FASTMELT Process

1. **Realizes faster speed and lower temperatures for the reduction reaction through carbon composite agglomerates.**
2. **Pre-treatment processes for raw material, which use large quantities of fuel, are not necessary**
3. **Since the secondary combustion efficiency in the rotary hearth furnace reaches almost 100%, which leads to a very high usage efficiency of coal, it is not necessary to recover and reuse exhaust gases.**
4. **Coal melter exhaust gas can be used as fuel for the rotary hearth furnace.**
5. **With respect to heat usage, the heat loss is low because the DRI is fed to the melting furnace for hot metal production without cooling (=hot charge).**

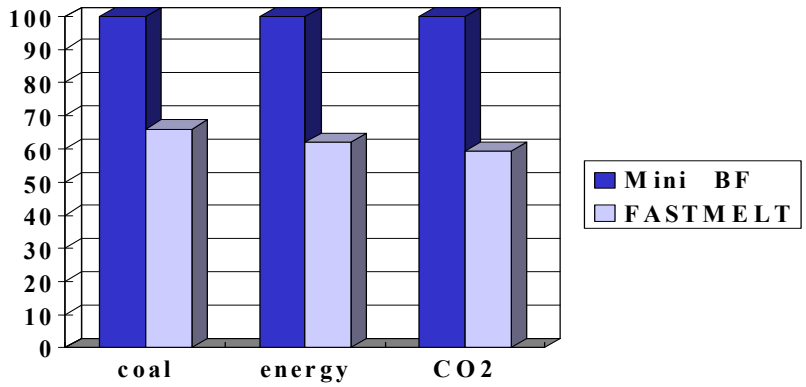
Emission of FASTMELT

	FASTMELT
NOx (kg/THM)	0.3 – 1.5
SOx (kg/THM)	2.4
PM10 (kg/THM)	0.3

Comparison of Total Energy Consumption and CO2 Emission

	Unit	FASTMELT	Mini?BF
Coal Consumption	(GJ/t-hm)	20.3	30.8
Energy Consumption	(GJ/t-hm)	20.0	32.3
CO2 Emission	(kg/t-hm)	1,804	3,045

Comparison of Coal Consumption, Energy Consumption and CO2 Emission



Conclusion

1. Direct Reduction process is superior with respect to energy conservation and environmental protection.
2. Considering the requirements in terms of iron works, raw material and fuel in China, a Direct Reduction process that is based on a relatively small scale and based on coal is suitable.
3. The FASTMELT process, a coal-based DRI production process, is superior with respect to energy conservation and environmental protection. It can substitute the numerous small blast furnaces currently existing in China.

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3.3.3 ITmk3® Ironmaking Process

United States - Best Available Technologies for Ironmaking

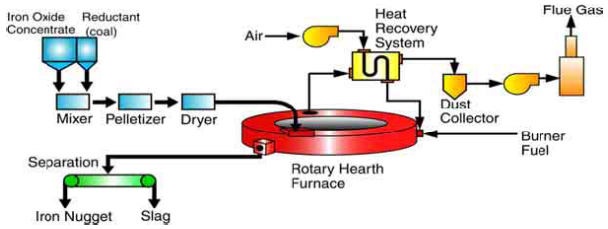
3.3.3 ITmk3 Ironmaking Process

ITmk3® Ironmaking Process

High-Quality Iron Nuggets Produced From Low-Grade Ore

The ITmk3® process uses low-grade ore to produce iron nuggets of superior quality to direct reduced iron and similar quality to pig iron, suitable for use in electric arc furnaces, basic oxygen furnaces and foundry applications.

Developed by Kobe Steel of Japan, the ITmk3® process uses a rotary hearth furnace to turn low-grade iron ore fines and pulverized coal into high nugget purity. Reduction, melting, and slag removal occur in just 10 minutes.



Flow sheet for the ITmk3® process illustrates the one-step furnace operation

Benefits

- **Energy** – Potential 30% energy savings over current 3-step integrated steelmaking; 10% savings for EAF steelmaking. All chemical energy of coal is utilized and no gas credit is exported.
- **Environment** – Eliminates coke oven or agglomeration plant; typical blast furnace can reduce emissions by more than 40%.
- **Costs** – Low capital and operating costs. Excellent operational reliability.

Commercialization

- First commercial facility constructed in 2005.
- Two or more production facilities planned, totaling over 1.6 million tons/year capacity.

Capabilities

- Produces high purity nuggets: 97% iron content. Utilizes low-grade ore
- Reduces FeO to less than 2%, minimizing attack to refractories

United States - Best Available Technologies for Ironmaking

The production of high purity nuggets allows higher scrap recycling in EAF and BOF to produce flat products of high quality steel due to dilution of tramp elements such as Cu, Pb, Sn, and Cr. In addition, it allows the mining industry to widen their market by supplying nuggets directly to all melt shops at the BOF, EAF, and foundry facilities.



Iron nuggets produced at the Mesabi Nugget pilot plant



Inside the Mesabi Nugget pilot plant

Contact
Mesabi Nugget, LLC
http://mesabinugget.com

Sources

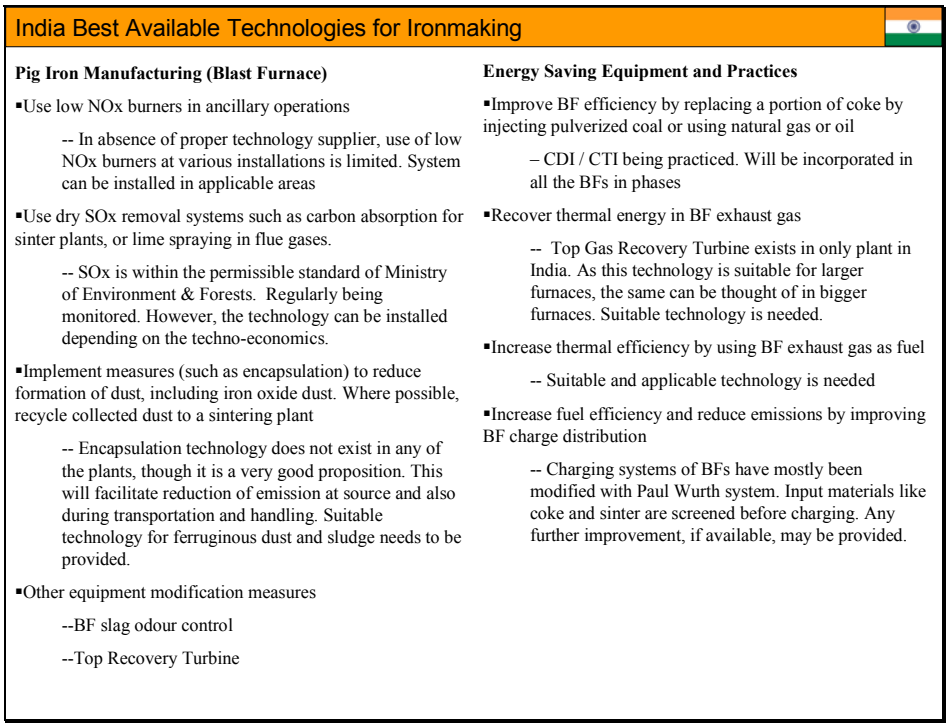
- Industrial Technologies Program, *Impacts*, February 2006, p. 127
- Industrial Technologies Program fact sheets www.eere.energy.gov/industry/steel
- Mesabi Nugget process information

3.1.1 Top Pressure Recovery Turbine,

3.1.2 Pulverized Coal Injection System,

3.1.4 Improve Blast Furnace Charge Distribution, &

3.1.7 Slag Odor Control



India Best Available Technologies for Ironmaking

Pig Iron Manufacturing (Blast Furnace)

▪Use low NOx burners in ancillary operations

-- In absence of proper technology supplier, use of low NOx burners at various installations is limited. System can be installed in applicable areas

▪Use dry SOx removal systems such as carbon absorption for sinter plants, or lime spraying in flue gases.

-- SOx is within the permissible standard of Ministry of Environment & Forests. Regularly being monitored. However, the technology can be installed depending on the techno-economics.

▪Implement measures (such as encapsulation) to reduce formation of dust, including iron oxide dust. Where possible, recycle collected dust to a sintering plant

-- Encapsulation technology does not exist in any of the plants, though it is a very good proposition. This will facilitate reduction of emission at source and also during transportation and handling. Suitable technology for ferruginous dust and sludge needs to be provided.

▪Other equipment modification measures

--BF slag odour control

--Top Recovery Turbine

Energy Saving Equipment and Practices

▪Improve BF efficiency by replacing a portion of coke by injecting pulverized coal or using natural gas or oil

– CDI / CTI being practiced. Will be incorporated in all the BFs in phases

▪Recover thermal energy in BF exhaust gas

-- Top Gas Recovery Turbine exists in only plant in India. As this technology is suitable for larger furnaces, the same can be thought of in bigger furnaces. Suitable technology is needed.

▪Increase thermal efficiency by using BF exhaust gas as fuel

-- Suitable and applicable technology is needed

▪Increase fuel efficiency and reduce emissions by improving BF charge distribution

-- Charging systems of BFs have mostly been modified with Paul Wurth system. Input materials like coke and sinter are screened before charging. Any further improvement, if available, may be provided.

4.0.1 Electrochemical Dezincing - Dezincing of Steel Scrap Improves Recycling Process

United States - Best Available Technologies for EAF Steelmaking*

Electrochemical Dezincing

Dezincing of Steel Scrap Improves Recycling Process

This electrochemical dezincing process provides an environmentally-friendly, economic method of removing zinc from steel scrap to reuse both the steel and zinc.

With the use of zinc-coated prompt scrap increasing, steelmakers are feeling the effect of increased contaminant loads on their operations. The greatest concerns are the cost of treatment before disposal of waste dusts and the water associated with remelting zinc-coated scrap.



Benefits

- **Pollution Reduction –** Removal of zinc decreases steelmaking dust released to the air as well as pollutants in wastewater streams. The process itself does not consume any chemicals (other than drag-out losses) and produces only a small amount of waste.
- **Productivity –** Removing zinc prior to processing of scrap saves time and money in disposal of waste dusts and water. Without the zinc, this high-quality scrap does not require extra handling, blending, or sorting for remelting in steelmaking furnaces

Commercialization

- Commercialized in 2003

Capabilities

- Improves quality of steel scrap
- Produces 99.8% pure zinc for resale

*** Also applicable to BOF Steelmaking**

United States - Best Available Technologies for EAF Steelmaking

Process Summary

The dezincing technology separates steel scrap into dezinced steel scrap and metallic zinc.

The removal of zinc from steel scrap increases the recyclability of the underlying steel, decreases steelmaking dust, and decreases zinc in wastewater streams.

The process consists of two basic steps:

1) dissolving the zinc coating from scrap in a hot, caustic solution, and

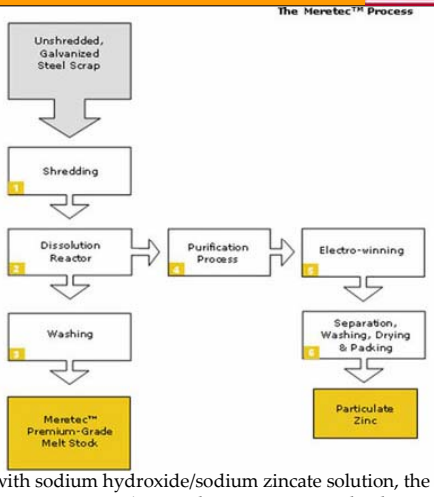
2) recovering the zinc from the solution electrolytically.

Through a galvanic process, the zinc is removed from the steel and is in solution as sodium zincate ions rather than zinc dust. The steel is then rinsed with water and ready for reuse. Impurities are removed from the zinc solution, and then a voltage is applied in order to grow metallic zinc via an oxidation-reduction reaction. All waste streams in this process are reused.





Process Details



1. Shredding
The electro-chemical dissolution of the zinc coating of galvanized steel is greatly enhanced by a large number of penetrations of the zinc coating. This is achieved by means of a shredder, which breaks down the in-feed into consistently sized pieces. It is also more effective operationally to process homogenous in-feed rather than having to process a variety of sizes of scrap.

2. Dissolution Reactor - Zinc Removal
The shredded in-feed enters the dissolution reactor on a continuous basis. The reactor, which washes the in-feed in sodium hydroxide solution, has two functions: (1) to electrochemically dissolve the zinc coating on the galvanized steel and (2) to make the initial separation of the dezinced steel and the dissolving solution (which now contains the zinc)

3. Washing - Steel Cleaning Processes
The de-zinced steel exits the dissolution reactor out onto the first of two vibratory conveyors. However, at this stage the steel is still wet with sodium hydroxide/sodium zincate solution, the majority of which is shaken off as the steel progresses along the vibrating conveyor. A second conveyor rinses the de-zinced steel free of any remaining solution by a three-stage rinse system.

4. Purification Process
The "pregnant" (full of zinc) solution is pumped from the concrete overflow tank. Most of the solution is sent through the heat exchanger and passed by fluid from the thermal fluid heater, then reintroduced into the drum. The remaining solution is sent to the iron oxidizing mixing tank where Meretec zinc powder is added. During its residence in the iron oxidizing mixing tank, the iron precipitates as a result of the addition of zinc powder and agitation. The solution is then pumped through a cyclone where the iron solids are discharged and the overflow is sent to the pregnant solution tank. The pregnant solution is now ready for introduction into the electro-winning process.

United States - Best Available Technologies for EAF Steelmaking

5. Electro-winning
From the dissolution reactor and vibratory-conveyor pump boxes, the zinc-rich solution is sieved to remove any particles of zinc larger than a grain of sand and then pumped into a tank in the tank farm. The solution is then pumped to a cooling tower where it is cooled and pumped into the electro-winning cells.



Using an overflow system, the zinc-rich solution is fed into electro-winning cells, each containing magnesium cathodes and stainless steel anodes. The potential difference between the anodes and cathodes in the cell causes the zinc to come out of the solution and through electrolysis to deposit on the magnesium cathodes. By a process of vibration, the deposited zinc is removed from the cathodes and falls to the bottom of the cell, from where it enters a valve system before finally being flushed into an outflow pipe.

6. Separation, Washing, Drying and Packing
The zinc powder is dried in a multiple hearth system and stored in a nitrogen atmosphere to prevent oxidization. The zinc powder is then packaged in the relevant containers.



Contact
Meretec Corporation
www.meretec.com

Sources
- Industrial Technologies Program, *Impacts*, February 2006, p. 60
- Meretec Corporation product information

4.0.2 MultiGas™ Analyzer – On-Line Feedback for Efficient Combustion

United States - Best Available Technologies for BOF Steelmaking*

MultiGas™ Analyzer

On-Line Feedback for Efficient Combustion

The MultiGas™ analyzer improves continuous emissions monitoring (CEM) and on-line process tuning of combustion-dependent systems such as boilers, turbines, and furnaces.

The multi-gas analyzer allows real-time measurements of criteria emissions and hazardous air pollutants. The analyzer is portable, compact, low cost, and energy efficient, potentially lowering CEM operational energy use by 70 percent.



Benefits

- **Environmental –** Measures criteria and hazardous air pollutants that are not typically monitored on-site in real-time, such as formaldehyde and ammonia.
- **Productivity –** Reduces maintenance and performance verification time, resulting in labor savings of up to 80%.

Commercialization

- Commercialized in 2001

Capabilities

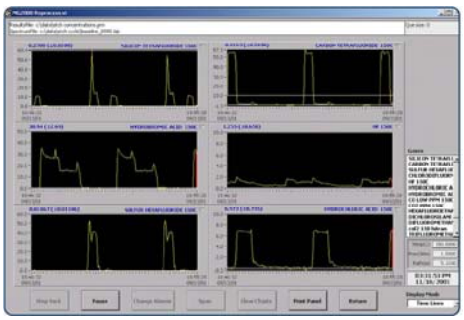
- Achieves higher combustion efficiencies through closely monitored and controlled combustion.
- Reduces emissions through verified efficient operation.

*** Also applicable to EAF Steelmaking**

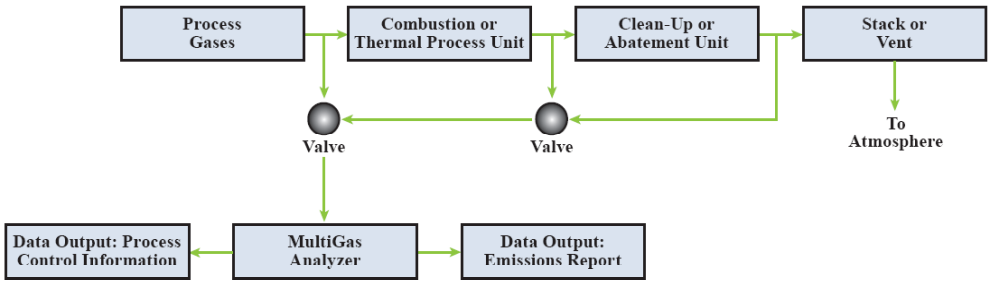
United States - Best Available Technologies for BOF Steelmaking

System Overview

The new multi-gas analyzer technology combines advanced Fourier transform infrared spectroscopy with advanced electronics and software. This system provides CEM and on-line feedback for operational tuning of combustion-based industrial processes. The system allows for real-time measurement of criteria emissions and pollutants, including pollutants that are not usually monitored such as formaldehyde and ammonia. The improvements in dependability and efficiency and the lack of need for expansive temperature-controlled space result in lower operations, energy, and labor costs.



Above: The MultiGas analyzer allows operators to simultaneously analyze and display over 30 gases.



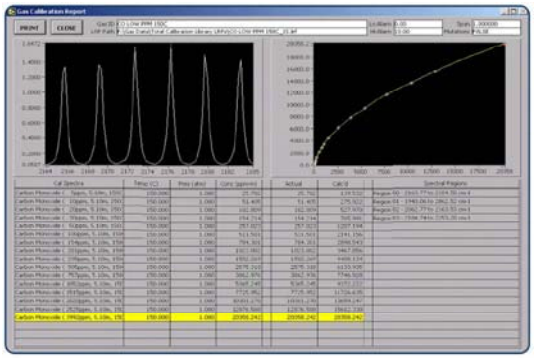
United States - Best Available Technologies for BOF Steelmaking

Instrument Independent Calibration

The MultiGas software uses multi-point calibration curves to provide a dynamic range up to 9 orders of magnitude (ppb to 100%). Calibrations for many species are provided with the instrument, and additional calibrations can be generated by the user from gasses of known concentration.

Spectral Analysis

The MultiGas software can analyze and report concentrations for dozens of compounds simultaneously. The software performs automatic corrections for gas temperature and pressure variations, which are measured directly by the analyzer. Samples can be acquired and analyzed in less than a second, making transient analysis possible.



Above: The graphical user interface for calibration

Contact
MKS Instruments, Inc.
www.mksinst.com

Sources
- Industrial Technologies Program, *Impacts*, February 2006, p. 71
- MKS Instruments product information

4.0.3 ProVision Lance-based Camera System for Vacuum Degasser - Real-Time Melt Temperature Measurement

United States - Best Available Technologies for BOF Steelmaking*

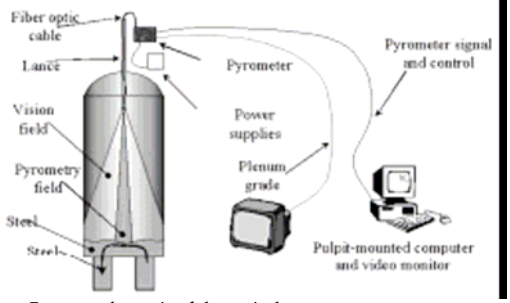
Optical Pyrometer for Vacuum Degasser

Real-Time Melt Temperature Measurement

The lance-based fiber-coupled optical pyrometer measures melt temperature in a vacuum degasser, used for producing ultra-low carbon steel through ladle treatment operation.

Temperature control in the ladle is crucial to downstream processes, especially in the continuous caster. To produce desired grades of steel, process models based on melt temperature and chemistry measured after tapping from the iron conversion vessel (BOF, Q-BPO, or EAF) and the ladle treatment station are used to determine degassing duration, amount of additional additive (if any), and amount of oxygen blowing.

The pyrometer eliminates manual or robot-operated thermocouples. It measures melt temperature automatically before and after oxygen blowing.



Process schematic of the optical pyrometer

Benefits

- Reduction in process time, enabling additional heat of steel per day and increased production value
- Reduction of energy use due to reduced processing time
- Potential emissions reductions per installation/ year of 550 tons of CO_2, 2.5 tons of NO_2, 5.3 tons of SO_2, and 1.93 tons of particulates

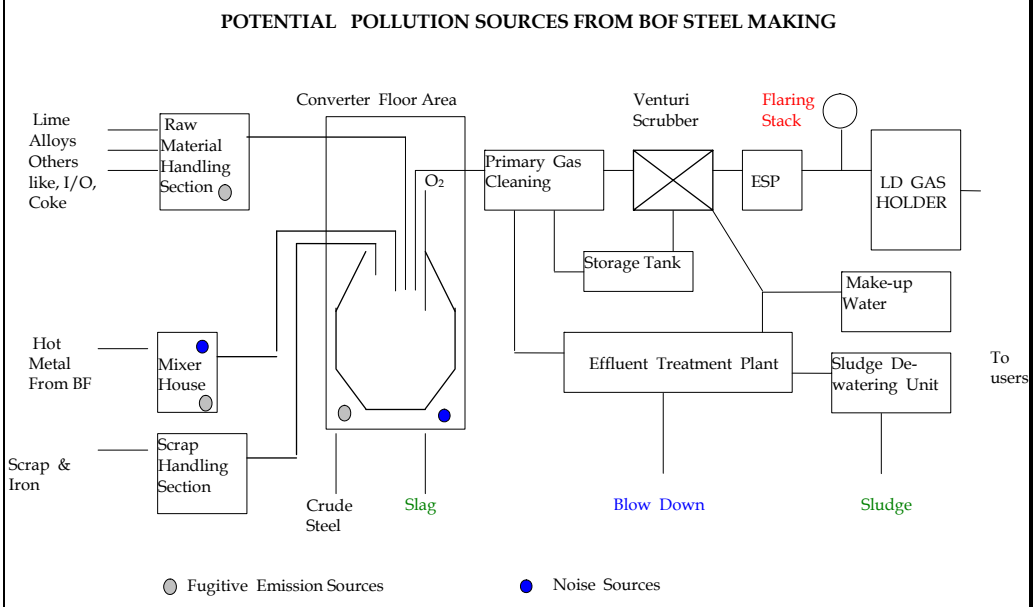
Contact
Process Metrix
www.processmetrix.com

Sources
- AISI fact sheet 0034, www.steel.org

*Also applicable to EAF Steelmaking

4.1 BOF Steelmaking - Background

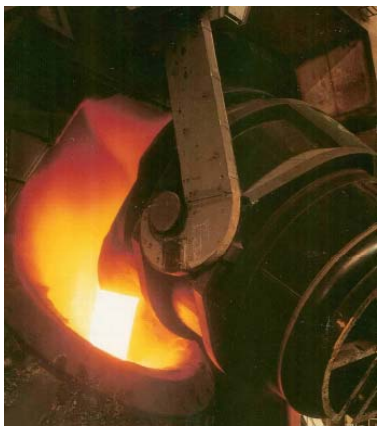
India Best Available Technologies for Ironmaking



Japan - Best Available Technologies for BOF Steelmaking

Basic Oxygen Furnace (Converter)

<Table of Contents>



1. Converter Steel Making Process
2. Exhaust Gas Treatment Equipment
3. Dedusting Equipment
4. Waste Water Treatment Equipment

Japan Iron and Steel Federation

Introduction (1/3)

- In the steel making process, the basic oxygen furnace (BOF) or converter refines steel by reducing the carbon content of pig iron made by the blast furnace from about 4.5% to 0.03-1.0%.
- The converter blows a large amount of pure oxygen into hot metal made by the blast furnace and refines steel in a short period of time. Currently, the top and bottom-blown converter is mainly used.
- Various materials are used for refining by the converter, including hot metal and iron scrap as main raw materials, and limestone, mill scale, iron ore, and fluorite as slag making materials.
- Therefore, the operation of the converter requires the gas temperature to be set high, and generates a large amount of dust.

Japan - Best Available Technologies for BOF Steelmaking

Introduction (2/3)

We apply appropriate treatment for emissions from the converter that create a significant environmental burden, and effectively use such emissions as energy sources and materials for steel making.

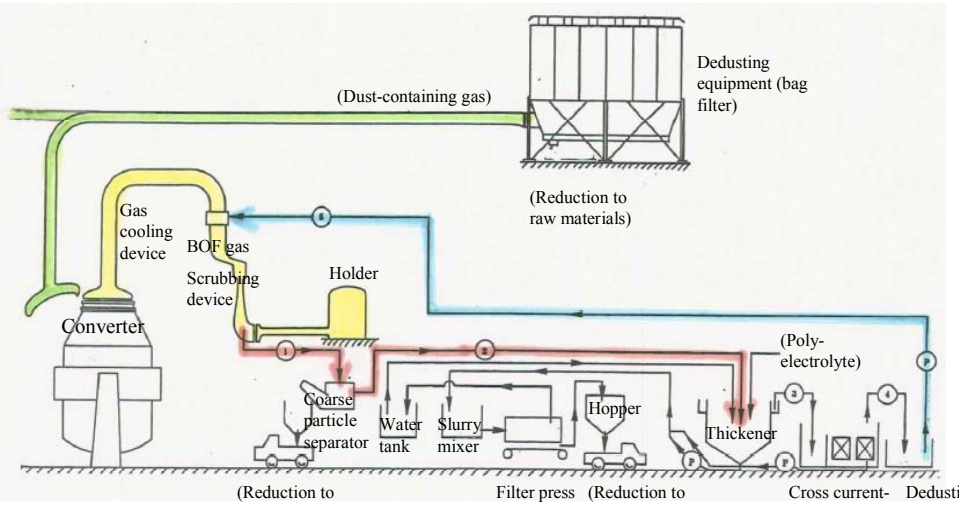
(Details on slag are left for another address.)

The rate of installation of exhaust gas treatment equipment and dedusting equipment is 100%.

<table>
<tr><th>Issues</th><th colspan="2">Equipment</th><th>Recovery</th><th>Recycling</th></tr>
<tr><td rowspan="2">High-temperature gas</td><td rowspan="2">Exhaust gas treatment equipment</td><td>Cooling</td><td>Thermal energy recovery</td><td>Steam</td></tr>
<tr><td>Cleaning</td><td rowspan="2">Dust collection</td><td>Fuel gas</td></tr>
<tr><td>Dust (colored smoke)</td><td colspan="2">Dedusting equipment</td><td>Materials for steel making</td></tr>
</table>

Source: JISF

Introduction (3/3) Example of the Converter Dedusting System



Japan - Best Available Technologies for BOF Steelmaking

1.1 Converter Steel Making Process

- The oxygen top-blown converter (LD converter) was an important innovation in the industrial science of steel making technology in Japan in the post-war period.

  However, this method had a fundamental problem in that agitation of the bath was weak in the low-carbon area.
- The oxygen bottom-blown converter developed in 1968 was poor at slag making and dedusting because agitation of the bath was too strong.
- The top and bottom-blown converter was invented as a new refining method with the strengths of the top-blown converter and bottom-blown converter combined together. Development of this method has been promoted mainly in Japan since the second half of the 1970s.
- Currently, top and bottom-blown converters, top-blown converters, and bottom-blown converters account for 92%, 5%, and 3%, respectively.

Source: JISF

1.2 Pre-Treatment of Hot Metal

- Ingredients of hot metal vary depending on the raw materials charged into the blast furnace and the operational conditions.
- The ingredient composition of hot metal required in the steel making process depends on the final ingredient composition, steel making process, and production efficiency. Therefore, pre-treatment of hot metal should be conducted appropriately according to the ingredient composition of hot metal, steel making and refining methods, and type of steel produced.
- However, since some desulfurization agents evaporate significantly at a melting point of 1,300 degrees C or higher, sufficient environmental measures should be implemented.

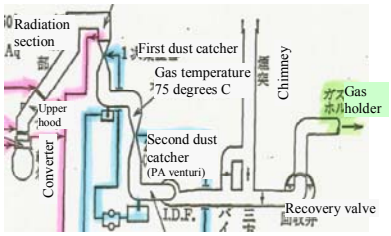
2. Dedusting Equipment (1/2)

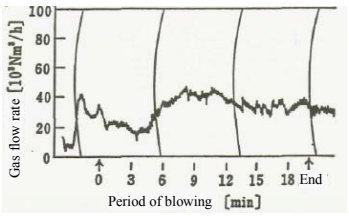
- Efforts have been made to prevent power dust from being generated in the converter plant.
- Dust is generated most significantly in the operation stages such as transferring hot metal from the torpedo car or hot metal mixer to the charge ladle, charging hot metal from the ladle into the converter, and tapping iron from the converter. Dust is also generated during the process of handling flux and cooling, and raking slag.
- In order to collect such dust, large dust catchers with an air volume up to over 10,000 m^3/min., are installed depending on the volume of the converter and/or the number of converters.



2. Dedusting Equipment (2/2)

- In some plants, dust catchers with a volume of several thousand cubic meters/min., are installed at points where dust is generated. As for the type of dust catchers, bag filters are popular, and both induced draft fans and forced draft fans are adopted.
- The electric motor required for the operation of the dust catcher is one of the largest motors used in the converter plant. For the purpose of saving electric energy, a revolution control device is used to change the number of revolutions depending on the induction load.

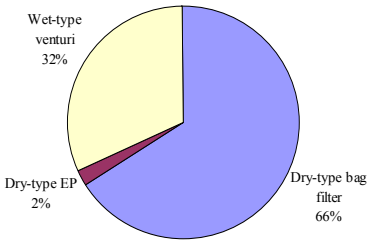




2.1 Examples of Dedusting Equipments

No.	Major equipment in which dust catchers are installed	Type of dust catcher	Volume of treated gas
1	Converter Torpedo 300t?1/2 600t	Bag filter	14,500m³/min
2	Converter Furnace ladle 300t?1/2 600t	Bag filter	16,000m³/min
3	Converter Hot metal mixer 250t?2/3 2500t	Bag filter	20,000m³/min
4	Converter Torpedo 250t?1/2 ??400t	Bag filter	20,000m³/min
5	Converter Torpedo 200t?2/3 350t	Bag filter Venturi scrubber	13,600m³/min 4,300m³/min
6	Converter Hot metal mixer 180t?2/3 1800t	Bag filter	14,000m³/min
7	Converter Hot metal mixer 90t?2/3 1100t	Electrical dust catcher	13,000m³/min

Distribution of dedusting equipment (47 units)



Source: JISF

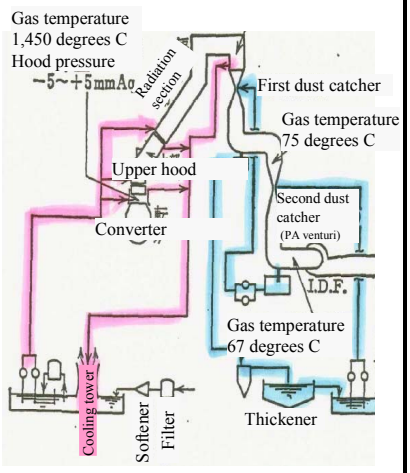
3. Waste Water Treatment Equipment

3.1 Characteristics of waste water in the converter process

Category	Waste water quality		Contaminant
Flow rate	18,700?72,000	m^3/D	
pH	8.4?12		
COD	3.5?720	mg/L	Molten iron (bivalent)
SS	1,277?5,830	mg/L	Iron oxide

3.2 Condition of Waste Water Treatment

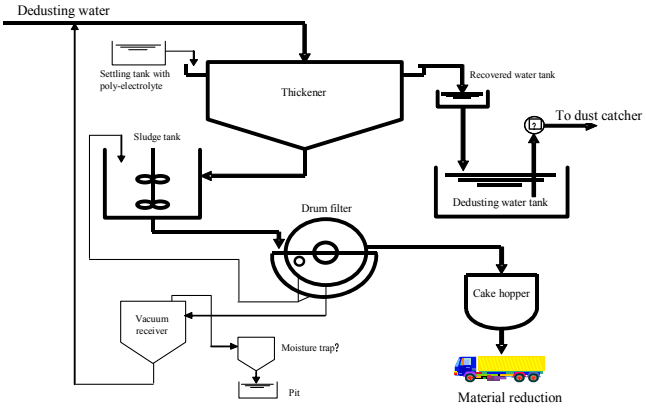
- The amount of dust contained in waste water discharged during gas scrubbing is about 1% of the total tonnage of the production of the converter. Therefore, the dust concentration in waste water discharged during blowing is generally 2-5g/L but sometimes reaches 10g/L. However, the dust concentration in waste water fluctuates significantly because waste water is not markedly contaminated during the pre-treatment period.
- Water is used for exhaust gas scrubbing, wet-type dedusting, and also used for direct and indirect cooling. Circulating water is used for indirect cooling.



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3.3 Example of the Waste Water Treatment System in the Converter Process

Waste water discharged from the dust catcher contains dust, which mainly consists of fine grains of iron powder, at several dozen grams per cubic meters (SS: 1,000 to 6,000 mg/L). Dust is treated by agglutination and precipitation, and reused as material for steel making.



4.1.1 Increase Thermal Efficiency by Using BOF Exhaust Gas as Fuel, &

4.1.2 Use of Enclosures for BOF

India Best Available Technologies for BOF Steelmaking

❖**Oxygen steelmaking**

BOF converters have been installed replacing the OHFs in most of the steel plants in the 1st phase of modernization. Facilities for arresting the fugitive dust in the major generating sources had also come up with the new BOF systems. In absence of specific pollution control standards, these facilities have not been properly utilized for long and have mostly become defunct / obsolete.

Ministry of Environment & Forests is going to publish new standards and guidelines for pollution control.

The major assistance needed in steel making areas are: efficient secondary dust evacuation facility in the material handling area of SMS, pouring and tapping area in the mixer bays and also to arrest the secondary emissions of BOF converter and associated areas. Here also, the major constraint faced is the space and logistic problem for retrofitting of efficient and effective dust extraction systems. Technological suppliers in this area are not available in India.

Assistance needed :

- ➢Efficient dust evacuation system in material handling area, mixer building, ferro-alloy section and ladle deskulling unit etc.
- ➢Secondary dust emission control from BOF converter
- ➢Dust evacuation system during ladling from torpedo ladles
- ➢Suitable dust control facility in secondary steel making
- ➢Efficient sludge dewatering facility
- ➢Suitable use of dust and sludge
- ➢Appropriate device for monitoring dust emissions
- ➢Alternate usage of BOF slag

Waste Heat Recovery

- Increase thermal efficiency by using BOF exhaust gas as fuel

  -- LD gas recovery system exists in most of the plants. But, due to various technological reasons, this gas is flared up presently instead of recovery in some of the units. Necessary assistance needed.

Energy Saving Equipment and Practices

- Use enclosures for BOF

  -- Capture of secondary emissions from BOF is not in practice except in one plant in India. There is tremendous pressure from the regulatory agency to control the secondary emissions. Space and logistic problems are the major hurdles in this area. Appropriate technology supplier / designer is urgently needed.

4.1.3 Control and Automization of Converter Operation

Japan - Best Available Technologies for BOF Steelmaking

1.1 Control and Automation of Converter Operation (1/2)

(i) Automated system

As converters have become larger, operational control and automatic operation have been promoted for the purpose of increasing productivity and product quality, saving labor, and improving the working environment.

In particular, along with the advancement of processing computers and peripheral measuring technology, blowing control for converters has shifted from a static control system to a dynamic control system, or a fully automatic operation system.

Japan - Best Available Technologies for BOF Steelmaking

1.1 Control and Automation of Converter Operation (2/2)

(ii) Blowing control

Indirect measurement by the exhausted gas method is employed in Europe and the United States, whereas direct measurement by the sublance method is employed in Japan.

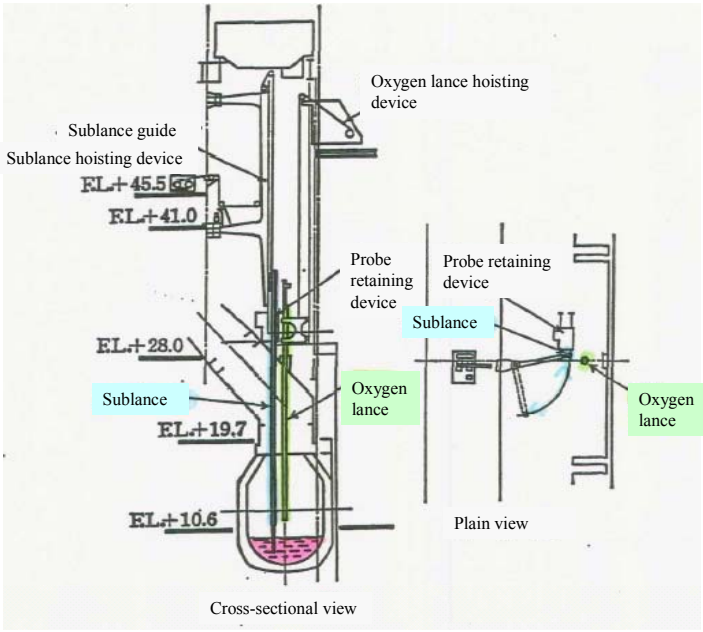
<Sublance method>

Direct measurement of the temperature (in degrees C) of molten steel simultaneously during blowing.

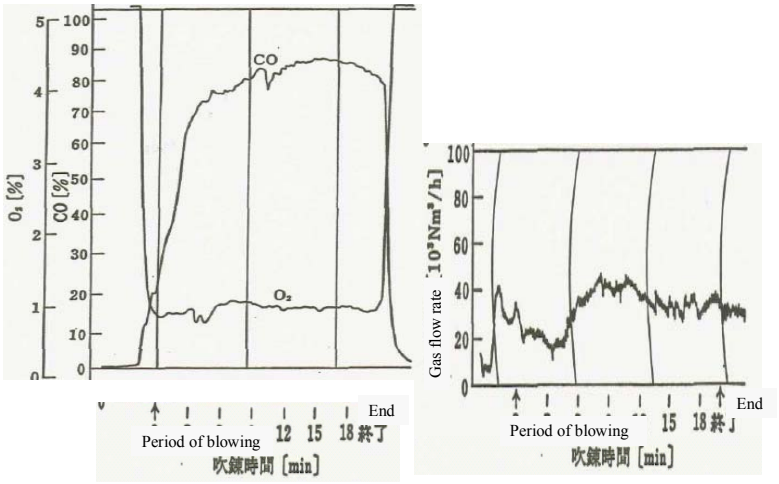
This method is used for various purposes such as bath leveling, slag leveling, measurement of oxygen concentration, and slag sampling.

Rapid reactions within the converter cause bumping of slag and molten steel, resulting in fluctuation in the throat gap control, or in the ingredient composition, or in the quantity of exhaust gas. To ensure quality and environmental protection, proper operation is essential.

1.1.1 Overview of Sublance Equipment



1.1.2 Gas Change in the Converter During One Blowing Cycle



1.1 Control and Automation of Converter Operation (2/2)

(ii) Blowing control

Indirect measurement by the exhausted gas method is employed in Europe and the United States, whereas direct measurement by the sublance method is employed in Japan.

<Sublance method>

Direct measurement of the temperature (in degrees C) of molten steel simultaneously during blowing.

This method is used for various purposes such as bath leveling, slag leveling, measurement of oxygen concentration, and slag sampling.

Rapid reactions within the converter cause bumping of slag and molten steel, resulting in fluctuation in the throat gap control, or in the ingredient composition, or in the quantity of exhaust gas. To ensure quality and environmental protection, proper operation is essential.

1.2 Exhaust Gas and Dust Generated from the Converter Operation

- 1) Dust concentration: Since steel refining is conducted in a short period of time, about 35 minutes per charge, the dust concentration is very high, usually about 15-25g/m^3N at the inlet of the stabilizer, although in the case of the combustion-type converters, it depends on the amount of combustion air.

  On the other hand, in the case of non-combustion-type converters with a gas recovery function, the dust concentration is 70-80g/m^3N at the inlet of the first dedusting device.
- 2) Grain size and ingredients of dust: Dust after the pre-treatment at the stabilizer or first dedusting device is fine grain with a median diameter of 0.2μm, mainly consisting of iron oxide ore.

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1.2 Exhaust Gas and Dust Generated from Converter Operation

- 3) Ingredients of exhaust gas: Ingredients of exhaust gas vary along with the process of the converter operation. Combustion-type converters oxidize CO into CO_2 through combustion, in order to prevent an explosion in the smoke duct or treatment equipment, whereas non-combustion-type converters, without combusting CO gas, manage the volume of intake air from the throat, and control the concentration so as to be below the explosion limit, thereby recovering CO as fuel.

- For the purpose of stabilizing such variation, pre-treatment of hot metal is conducted before hot metal is charged into the converter.

4.1.4 Exhaust Gas Cooling System (Combustion System)

Japan - Best Available Technologies for BOF Steelmaking

1. Exhaust Gas Treatment Equipment

Exhaust gas treatment equipment consists of an exhaust gas cooling system and a cleaning system.

(1) Exhaust gas cooling system

Gas generated during blowing mainly consists of high-temperature CO gas (about 1,400 degrees C) that contains fine-grain iron oxide powder. It is generated intermittently, and yet, appears in a large amount. There are two methods of exhaust gas treatment: combustion-type and non-combustion type.

(2) Cleaning system

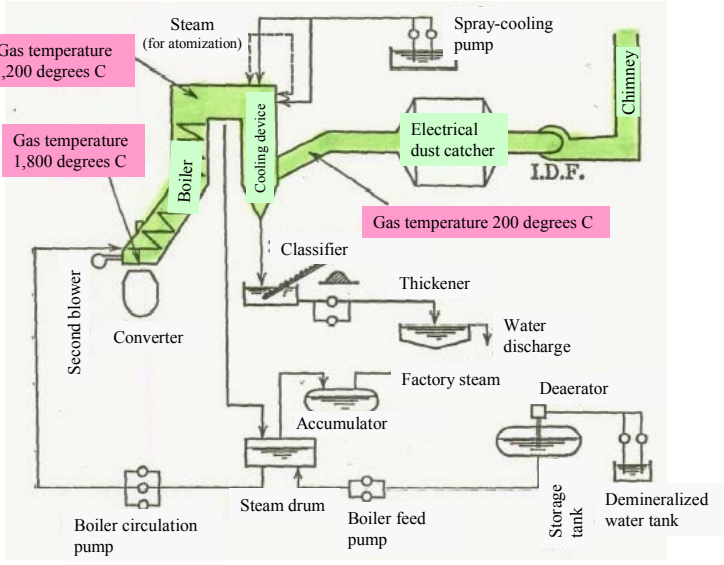
The dust content of exhaust gas generated during blowing is about 10kg/t in unit consumption. Its chief ingredient is iron oxide powder, accounting for at least about 60% in effective Fe equivalent.

1.1 (1) Exhaust Gas Cooling System: (i) Combustion Type

- The general combustion-type system is provided with sufficient space between the converter throat and the hood. The second blower sufficiently sends the amount of air that is necessary for CO gas combustion. CO gas is combusted at the hood and the smoke duct into high-temperature gas (1,600 degrees C). The exhaust heat boiler recovers the latent heat and sensible heat of gas as steam through heat exchange.
- There are two types of steam recovery boilers, a full boiler equipped with a superheater and coal economizer, and a half boiler without such equipment. The temperature of gas at the boiler outlet is 300 degrees C for full boilers, and about 1,000 degrees C for half boilers.
- Dust must be removed prior to atmospheric discharge. There are several types of dust removal machines such as electrical precipitators, venturi scrubbers, and bag filters. Among them, electrical precipitators are the most popular.
- There are both wet-type and dry-type electrical precipitators. The dry type is more popular because the wet type has problems with sludge treatment and erosion control.

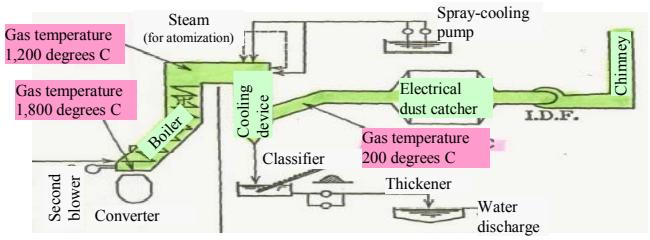
Japan - Best Available Technologies for BOF Steelmaking

1.1 (i) Combustion : boiler type



1.2 (2) Cleaning System (1/2)

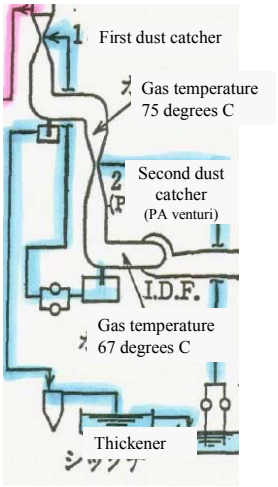
- The dust content of exhaust gas generated by blowing is about 10kg/t in unit consumption. Its chief ingredient is iron oxide, accounting for at least about 60% in effective Fe equivalent.
- In the combustion-type system, dust from the electrical dust catcher is separated from dust from the spray-cooling device. The former is recovered as dry dust and sent to the pelletizer, whereas the latter is recovered at the filter press via the thickener, and both are supplied to the sintering plant.



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1.2 (2) Cleaning System (2/2)

- In the non-combustion-type system that recovers exhaust gas as fuel, a dust catcher with a two-stage venturi scrubber is used as a major dedusting device for the converter.
- In the combustion-type system, apparent electric resistance of dust is about 1,012Ωm and back discharge occurs. Therefore, electrical dedusting is implemented after the stabilizer controls the humidity of exhaust gas sufficiently and the apparent electric resistance of dust is reduced.



4.1.5 OG-boiler System (non-combustion)/Dry-type Cyclone Dust Catcher

Japan - Best Available Technologies for BOF Steelmaking

1. Exhaust Gas Treatment Equipment

Exhaust gas treatment equipment consists of an exhaust gas cooling system and a cleaning system.

(1) Exhaust gas cooling system

Gas generated during blowing mainly consists of high-temperature CO gas (about 1,400 degrees C) that contains fine-grain iron oxide powder. It is generated intermittently, and yet, appears in a large amount. There are two methods of exhaust gas treatment: combustion-type and non-combustion type.

(2) Cleaning system

The dust content of exhaust gas generated during blowing is about 10kg/t in unit consumption. Its chief ingredient is iron oxide powder, accounting for at least about 60% in effective Fe equivalent.

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1.1 (1) Exhaust Gas Cooling System: (ii) Non-combustion Type (a)

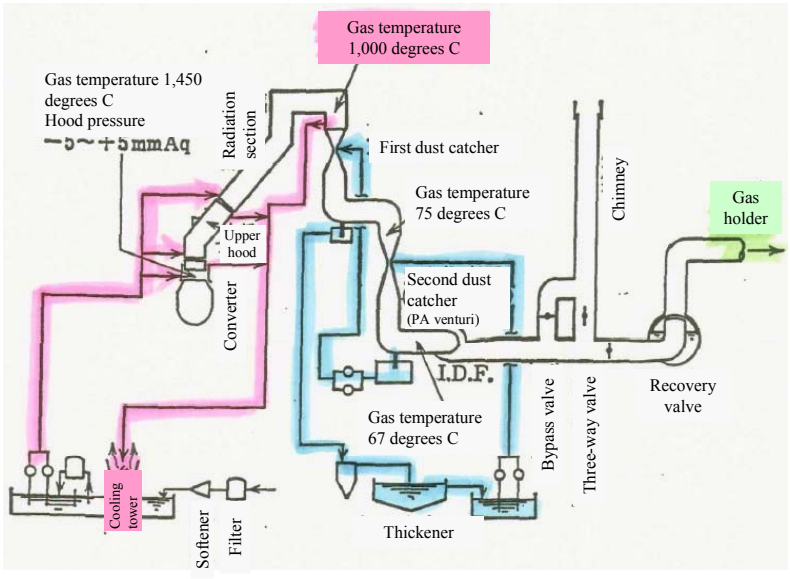
- In order to avoid combustion of exhaust gas, the general non-combustion-type system is provided with a skirt between the throat and the smoke ductto prevent air from coming in from the throat. Exhaust gas is recovered as uncombusted gas via the smoke duct of the gas cooling device and the wet-type dust catcher (e.g. venturi scrubber).
- The CO content of recovered gas is 60% or more, and the calorific value is 2,000 kcal/Nm^3. Recovered gas is used as fuel for rolling mills and lime firing furnaces.

1.1 (1) Exhaust Gas Cooling System: (ii) Non-combustion Type (b)

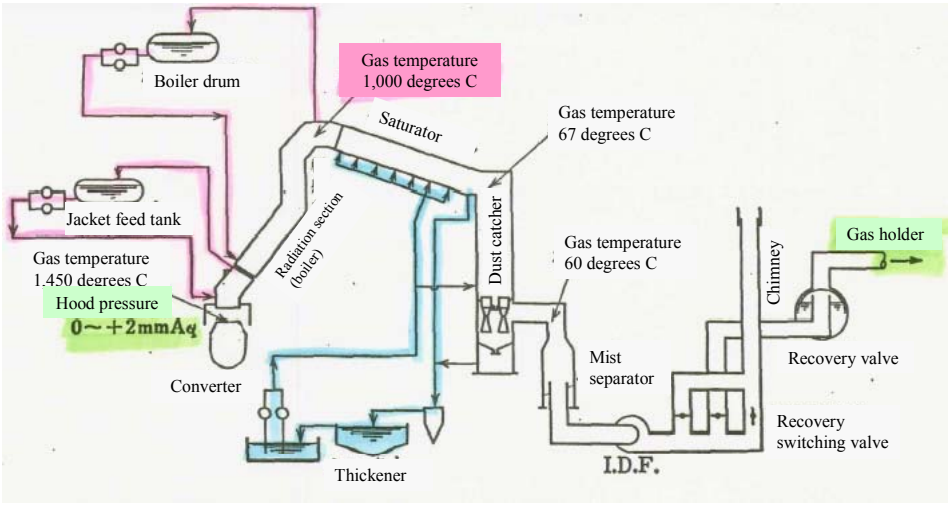
- Non-combustion-type systems can be largely divided into the OG-type and IC (IRSID-CAFL) type.
- The OG-type system basically has no space between the throat and the hood skirt, and controls pressure at the closed throat.
- The IC-type system has a gap of several hundred millimeters between the throat and the hood skirt (which has a slightly larger diameter than that of the throat), and controls pressure at the throat opening.

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1.1 (ii) (a) Non-combustion OG-Type



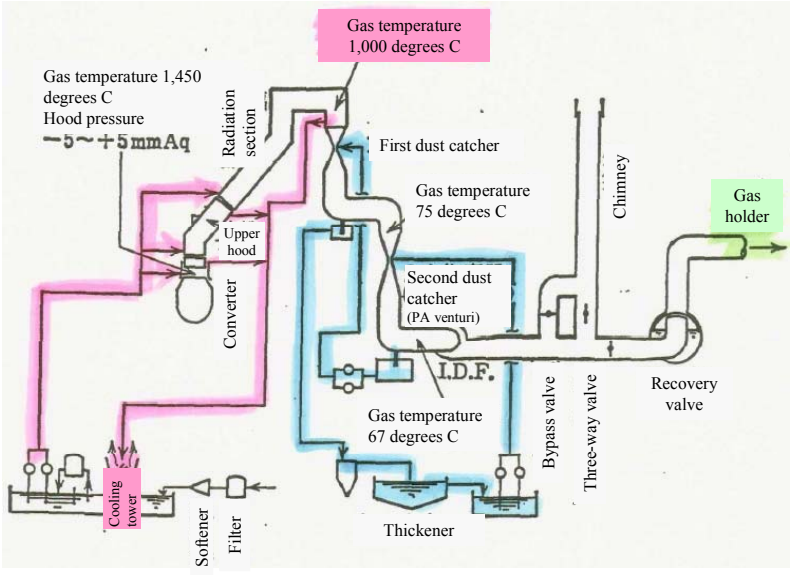
1.1 (ii) (b) Non-combustion IC-Type



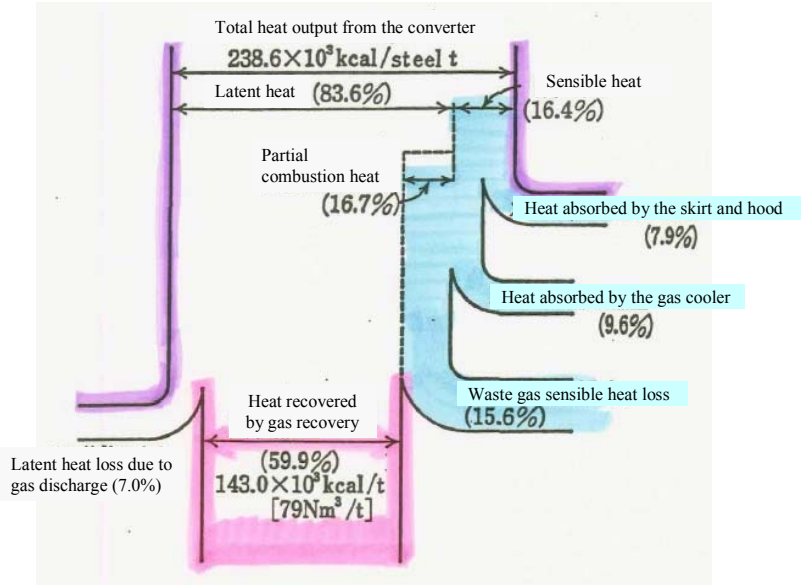
1.1. (1) Exhaust Gas Cooling System: (ii) Non-combustion Type (Summary)

- The non-combustion-type system keeps gas temperature low and shuts out combustion air, therefore, the cooling device and dedusting device installed in the system are smaller than those installed in the combustion-type system.
- Since the system handles gas that mainly consists of CO, attention is paid to sealing for the flux and coolant input hole and the lance hole, and leak control at the periphery of devices as well as purge at the gas retention part.
- As the volume of converters increases, exhaust gas treatment equipment becomes larger. Most recent large converters adopt the non-combustion-type system for various reasons, such as the relatively small size of the system as a whole, ease of maintenance, and stable dedusting efficiency.
- The OG-type system is frequently used because of its operational stability.

1.1 (ii) (a) Non-combustion OG-Type



1.1. (ii)(a)1. Heat Balance in the OG-Type System



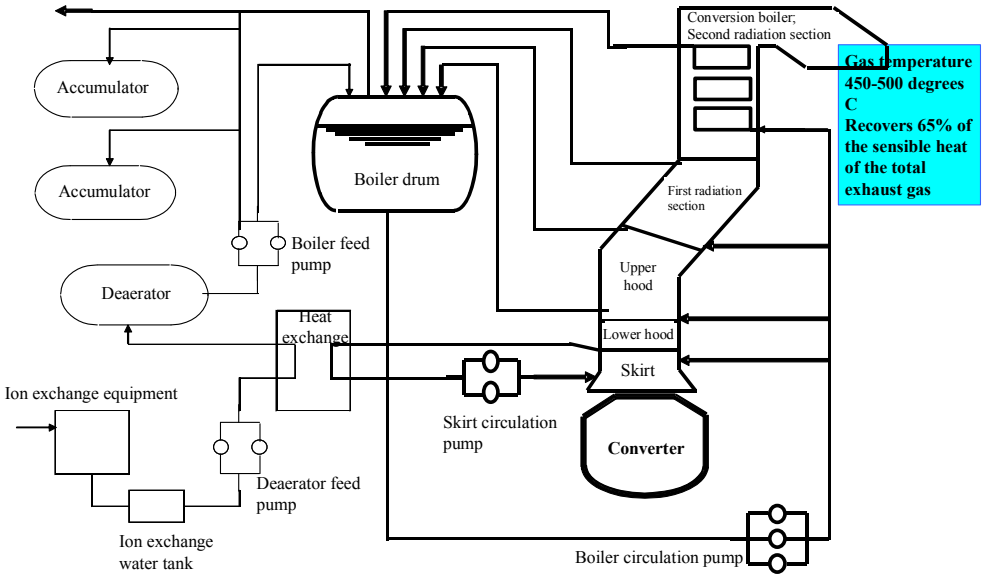
1.2 OG Boiler System

- For the purpose of simultaneous recovery of the sensible heat of exhaust gas, the OG boiler system, which is an OG-type cooling system, remodeled into the (non-combustion-type) boiler structure, has been introduced. This system makes it possible not only to recover the sensible heat of exhaust gas as steam, but also to increase the IDF efficiency by lowering the temperature of the exhaust gas by use of a cooling device.

- Reportedly, the representative OG boiler system recovers 65% of the sensible heat of the total exhaust gas (steam volume: about 70kg/t), and increases the IDF efficiency by lowering the temperature of the exhaust gas, thereby achieving high-speed oxygen feeding.

Japan - Best Available Technologies for BOF Steelmaking

1.2.1 OG Boiler System



1.3 Sealed OG System (1/2)

- The completely sealed OG system prevents the combustion of exhaust gas due to air coming through the throat, and maintains a high caloric value of exhaust gas. It is also expected to achieve high-speed oxygen feeding by reducing the exhaust gas flow rate.

- However, in order to operate the sealed system in the converter, various measures should be implemented to predict and absorb furnace pressure fluctuations arising from rapid reactions within the furnace, to ensure safety in emergency situations, as well as to provide a skirt to seal the throat and remove adherent bare metals.

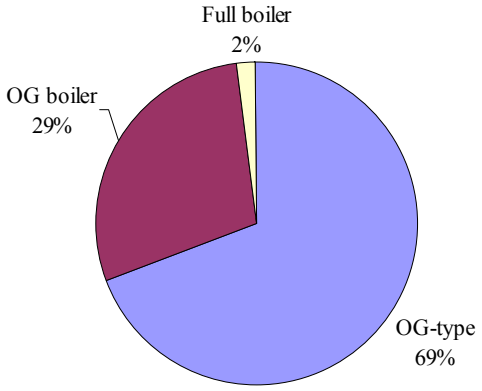
1.3 Sealed OG System (2/2)

- In the sealed OG process, that started operation in 1985, the throat is completely sealed by doubly sealing the skirt, and sealing devices are also installed for the lance hole and the flux and coolant input hole. Through the introduction of a new control system that was developed by applying an adaptive control system, the OG process can control furnace pressure within a range of $^{\pm}$25mmAq in distribution value.

- With these improvements, the OG system currently in operation has increased the amount of exhaust gas recovery by 10Nm^3/t-s. However, many operational problems still remain with respect to maintenance of the throat shape and prevention of slopping.

1.4 Diffusion Rate in Japan by Type of Equipment

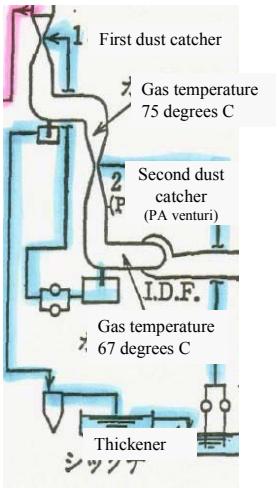
Distribution of exhaust gas treatment equipment (55 units)



Source: JISF

1.5 (2) Cleaning System (2/2)

- In the non-combustion-type system that recovers exhaust gas as fuel, a dust catcher with a two-stage venturi scrubber is used as a major dedusting device for the converter.
- In the combustion-type system, apparent electric resistance of dust is about 1,012Ωm and back discharge occurs. Therefore, electrical dedusting is implemented after the stabilizer controls the humidity of exhaust gas sufficiently and the apparent electric resistance of dust is reduced.



Japan - Best Available Technologies for BOF Steelmaking

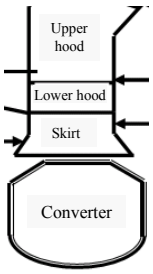
Closing: New Technology for the OG System

(1) Adopt the dry-type dust catcher

As the first dedusting device, research on a dry-type cyclone dust catcher is being conducted. As the second dedusting device, the LT system with an electrical dust catcher, which is categorized as a dry-type dedusting process, is popular mainly in Europe, and more than 20 units have been adopted. The dry-type system can reduce the burden of water treatment and is also expected to improve the reliability (resistance to corrosion) of equipment.

(2) Increase efficiency in exhaust heat recovery

We aim to install boilers in the hot section of the OG system and operate the converter with its throat sealed. This method will be effective at the hottest section, but in order to respond to rapid reactions within the furnace, various measures should be implemented to improve furnace pressure control and prevent adhesion of bare metals (slopping).



We carry out technology development with the aim of further promoting recycling, improving energy recovery, and strengthening equipment maintenance and environment protection. ???

4.1.6 Laser Contouring System to Extend Lifetime of BOF Refractory Lining

United States - Best Available Technologies for BOF Steelmaking

Laser Contouring System

Extending the Lifetime of BOF Refractory Lining

The Laser Contouring System allows rapid measurements of vessel wall and bottom lining thickness in the steel furnace or ladle environments.

The LCS measures refractory lining thickness and incorporates high-speed, laser-based distance measuring equipment with a robust mechanical platform and easy-to-use software. With a laser scan rate of over 8,000 points per second, a single vessel scan can include over 500,000 individual contour measurements, providing detailed contour resolution and accurate bath height determination.





Benefits

- **Energy Savings -** Reduces energy usage via rapid real-time measurements and no loss of process time.
- **Productivity -** Reduces maintenance on BOF refractory via automated furnace inspection.

Commercialization

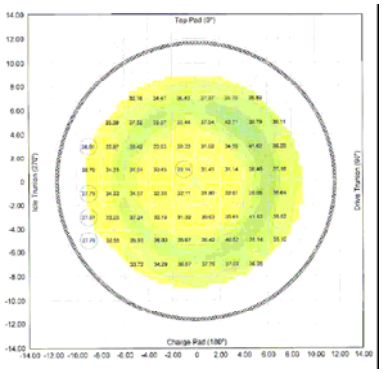
- First commercialized in 2001

Capabilities

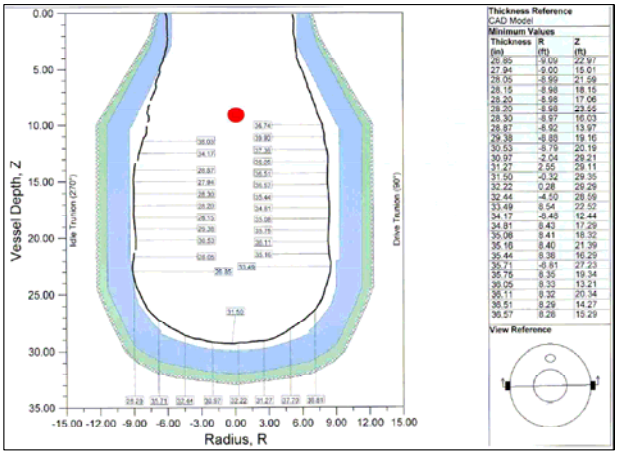
- Available as a mobile platform or a fixed position installation.
- Maps the entire vessel interior in less than 10 minutes.
- Provides detailed contour resolution and vessel lining thickness with over 500,000 individual contour measurements.

Refractory Contouring Software

Contour maps of both vessel wall and bottom illustrate lining thickness over the entire vessel interior. Thickness values are displayed both numerically and by color key, immediately revealing regions that might require attention. The report generator automatically prints all of the views and screens needed by the mill to make informed process decisions.



Above: LCS contour map of BOF bottom; lining thickness is indicated by color and given numerically.



Left: LCS software desktop, here illustrating a radial slice through the BOF trunion axis.

United States - Best Available Technologies for BOF Steelmaking

Mobile Platform

Two principle objectives are emphasized in the mobile platform design: speed and simplicity. Fast measurement times are achieved using a laser-based navigation system. Working from three reflectors mounted on the building structure behind the cart, this system automatically measures the cart position relative to the BOF and reports position information directly to the LCS computer. The navigation system is completely automatic and updates 8 times per second.

The system contains a radio frequency (RF) link that continuously broadcasts the vessel tilt to a receiver in the cart. The RF-link incorporates 2.4 GigaHertz spread-spectrum technology for interference-free transmission. During the measurement, the RF receiver automatically reports the vessel tilt to the LCS computer. Together, the laser navigation system and RF link enable fast, error-free measurement of the vessel lining thickness. Single measurements can be made in 20-30 seconds. An entire map of the vessel interior, consisting of 4-6 measurements and 500,000+ data points, can be completed in less than 10 minutes.



United States - Best Available Technologies for BOF Steelmaking



Fixed Position Installation

In addition to the mobile platform unit, a fixed position installation is available for converter and ladle applications. This type of installation coupled with the high measurement speed of the LCS enables measurements after every heat with little or no loss of process time.

Each fixed-position installation is custom engineered for the application and space constraints. The design should place the sensor as close to the vessel mouth as possible to maximize the field of view into the vessel. The sensor is typically located on the tap side to avoid conflicts with hot metal and scrap charging; tap floor, building columns, and hood area are other potential locations.

Contact
Process Metrix
www.processmetrix.com

Sources
- Industrial Technologies Program, *Impacts*, February 2006, p. 61
- Process Metrix product information

4.2 EAF Steelmaking - Background

India Best Available Technologies for EAF Steelmaking

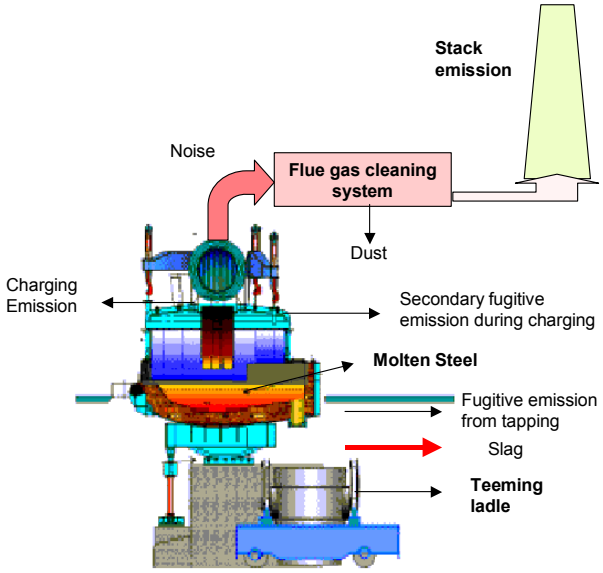
❖**EAF steelmaking**

EAFs are facing the problem of abnormally high fugitive dust emissions from its operation. The existing dust evacuation system attached to the fourth hole is not very effective causing high emission from the shop to the atmosphere during lancing. None of the EAFs are provided with Dog House facility causing high level of noise too. End use of EAF dust and slag is also a problem from regulatory point of view. Indigenous technology supplier for modern facility on the above areas is not available.

Assistance needed :

- ➢Control of high secondary emission
- ➢Use of EAF dust
- ➢Use of EAF slag
- ➢Control of high noise from EAF

India Best Available Technologies for EAF Steelmaking



EAF Steel making

4.2.1 Elimination of Radiation Sources in EAF Charge Scrap

United States - Best Available Technologies for EAF Steelmaking

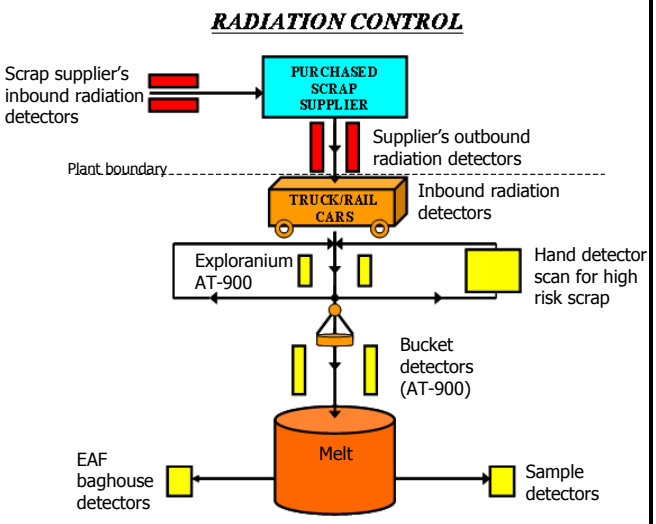
Elimination of Radiation Sources in EAF Charge Scrap

Methods for Ensuring Effective Radiation Control

Effective radiation control involves a redundant scan process to inspect incoming scrap material for hidden radiation sources.

Radiation Control Process

- Purchased scrap may undergo radiation detection by the supplier prior to delivery onsite.
- All incoming scrap to the facility is passed through the Exploranium AT-900 detection equipment. Scrap flagged as high risk undergoes additional scanning from hand detectors.
- A second scan with the AT-900 is performed prior to melt shop delivery.
- A final scan is performed on each magnet load as charge buckets are filled.
- EAF baghouse detectors define when, if any, radioactive material has been melted.



Schematic of Radiation Control Process

Source: The Timken Company

Effective Radiation Detection

Radiation Detection Technologies:

- Exploranium AT-900 on truck scales and rail scales
- Handheld survey equipment to inspect high risk loads and loads that have triggered an alarm from the AT-900
- Multi-channel analyzers to act as survey meters and identify the radioactive isotopes found in a load

Training Programs:

- Radiation Detector Alarm Response Training
- Radiation Source Identification Training
- Annual Skill Performance Evaluation

Contact
The Timken Company
www.timken.com

Exploranium AT-900 Series Radiation Portal Monitor:



Exploranium AT-900

Exploranium AT-900 details:



- A complete monitoring system used for the rapid detection of unknown hidden radioactive sources in moving vehicles, including trucks and railcars.
- Graphic real-time display shows vehicle position and status of radiation detection.
- Positive radiation identification triggers audible and visual alarms to the system operator, isolating the vehicle or container in question.
- The console is multi-lingual, featuring instructions in the user's chosen language.



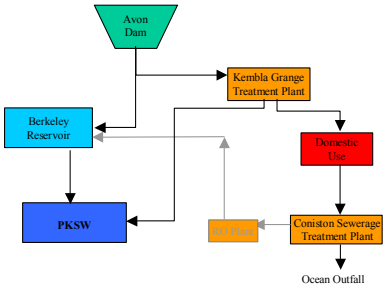
Source: www.saic.com

7.1 Reduced Fresh Water Use

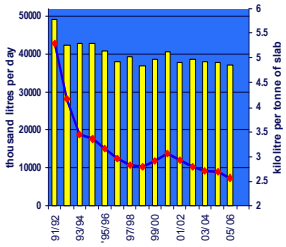
Australia - Best Available Technologies for Recycling

Reducing Fresh Water Use at Port Kembla Steelworks

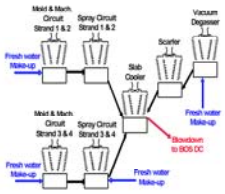
How water gets from the dam to PKSW



Historical trend of Steel Works water use



Water flow between the Slab Caster Cooling Towers.



Background

- Australia is experiencing a drought.
- Population in the Sydney Area is growing.

- The Port Kembla Steel Works is the biggest single user in the Sydney Area.
- Decision to reduce dependency on drinking quality (Dam) water.
- Extensive use of Salt Water, over 700 ML/day

What has been done

- Use high quality treated sewerage water (Reverse Osmosis) in the Industrial water circuit. Up to 20 ML/day
- Collection and recycle all run off and discharges from the Coke Ovens Area.
- Cooling tower blowdown used as often as possible.

Future Opportunities

- Dam and reuse water flowing through the site.
- Covert 5BF from salt water gas cleaning to recirculating fresh water.
- Install a TRT when 6 BF is relined in 2016.

7.2 Slag Recycling

India Best Available Technologies for Recycling

Slag and dust recycling

♣ **Blast Furnace Slag**

All the steel plants have off-site slag granulation plants. But, due to solidification of slag in transit and the non-availability of slag pots, production of granulated slag from these units was limited . Currently, on-site slag granulation facilities have been set up in some of the Blast Furnaces of SAIL and other ISPs.

Basically, the granulated slag is sold to nearby cement industries. But, at present **flyash** are available for free, as per govt. directive, cement industries are mainly manufacturing fly ash based cement. Also, the non-availability of secondary granulation facilities in the cement units has further reduced the utilization of granulated BF slag. Besides, use of granulated slag is also limited, in view of the number of cement industries nearby. Hence, alternate usage of BF slag needs to be explored. In SAIL and other ISPs, a portion of BF slag is air cooled and used in place of stone chips for internal road making. Use of BF slag for making slag wool, fertilizers etc. has to be investigated. However, a full fledged facility needs to be established for alternate usage of BF slag. Steel Plants may engage separate entrepreneurs who have sufficient knowledge and can investigate the market for off take of the slag.

♣ **Basic Oxygen Furnace (BOF) Slag**

BOF slag was previously cooled, crushed and dumped after separation of metals. Of late, after much persuasion, slag was sold to Railways from different units to be used as ballast. Due to inappropriate infrastructure for crushing and sizing of the slag, quantum requirement by Railways could not be met. The negotiation also subsided due to lack of entrepreneurship. Also use of BOF slag in iron making and sinter making units as a replenishment of flux also remained limited. Increased recycling of BOF superfines remained limited, also due to technological difficulties. A full-fledged slag disposal facility needs to be established by all ISPs for necessary off takes. Steel Plants may engage separate entrepreneurs who have sufficient knowledge and can investigate the market for off take of the slag.

♣ **EAF Slag**

So far, the EAF dust and slag are not being recycled or utilized in any way in the steel works. These two by-products are being dumped. There is pressure from the regulatory body for alternate use of EAF dust as these are hazardous in nature. Pelletising of EAF dust is not practiced in Indian Electric Furnace steel making.

India Best Available Technologies for Recycling

Slag and Dust Recycling

- Use of BF slag in construction materials. Slag containing free lime can be used in iron making – BF slag is employed for internal road maintenance with limited use.
- Use BOF slag in construction materials. Slag containing free lime can be used in iron making – BOF slag is partially recycled for iron making and sinter making
- Recycle collected dust to a sintering plant -- Partially recycled. Proper infrastructure for transportation of dust needs to be developed.

Environmental Measures

- Use dry dust collection and removal systems to avoid generation of waste water. Recycle collected dust

  --Technology is not available. However, the same can be thought of in new installations

- Re-circulate waste waters – Being practiced

- Treat waste water by using sedimentation to remove suspended solids; physical and chemical treatment to precipitate heavy metals; and filtration – Sedimentation technique is being practiced. Secondary treatment for heavy metal separation is not done. No stricture is there from regulatory authority.

- Stabilize solid wastes containing heavy metals by using chemical agents before disposal

  -- Waste streams have been identified. Suitable technology for use of chemical agents maybe provided

- BAT for treatment of waste acid sludge / acid recovery from Pickling Tank in Stainless Steel Pickling Line. This is particularly to be addressed to those processes using HF acid and ensuring problem of fluoride removal from waste water / effluent.

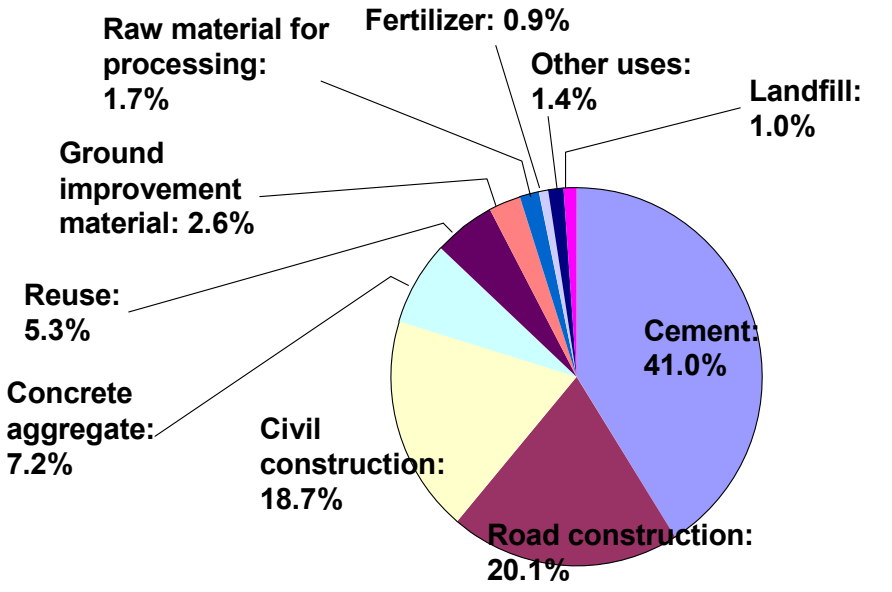
Japan - Best Available Technologies for Recycling

1. Current Use of Iron and Steel Slag

Implementation of activities by the industry as a whole

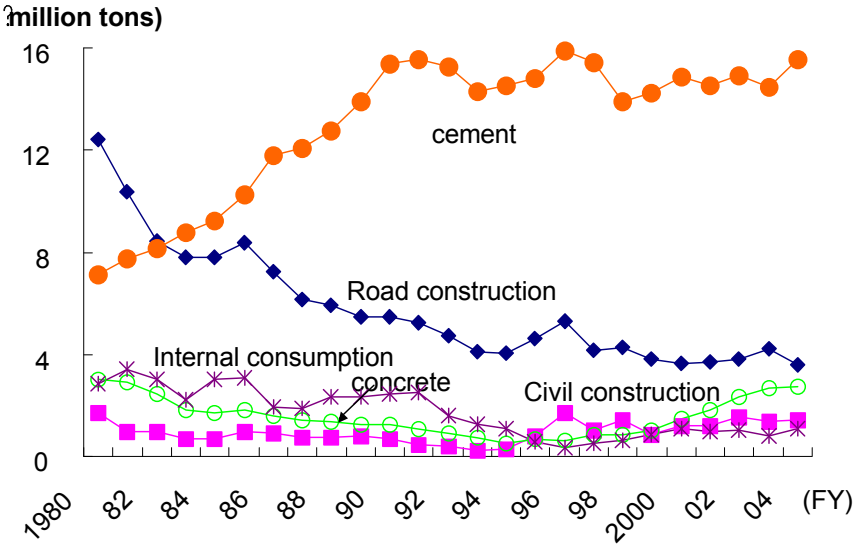
- **Development of use technologies** taking advantage of properties of slag
- Promotion of use in society by **standardization** under JIS, etc.

Total use (FY2004): 39 million tons

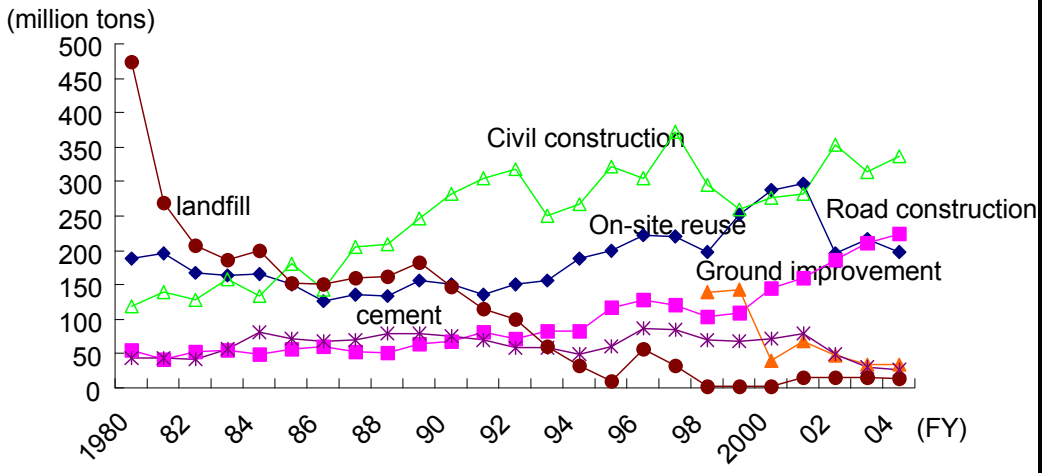


Japan - Best Available Technologies for Recycling

Transition of Blast Furnace Slag Use



Transition of Steel Slag Use



2. Society around Slag (Recycling Society)

Fundamental Law for Establishing a Sound Material-Cycle Society

Law for Promotion of Effective Utilization of Resources

Effective 2001

3Rs (Reduce/Reuse/Recycle)

1. Green Purchasing Law

Effective 2001

2. Law for the Recycling of Construction Materials

Effective 2002:

3. Soil Contamination Countermeasures Law

Effective 2003:

3.1 Green Purchasing Law

governmental bodies give priority to use of items

Designate procurement items

JISF(The Japan Iron Steel Federation) &NSA(Nippon Slag Association)

Actively emphasize the environmental superiority of slag

Japan - Best Available Technologies for Recycling

Slag as Designated procurement items

	FY	Judgment standard
Blast furnace cement	2001	Blast furnace slag > 30%
Steel slag aggregate	2002	Substitute for natural material
Roadbed material containing iron and steel slag	2002	Use of iron and steel slag in roads
Asphalt mixture containing iron and steel slag	2002	Use of iron and steel slag as aggregate
Rock wool using iron and steel slag as raw materials	2002	Slag > 85%
Granulated slag for port and harbor construction	2003	Blast furnace slag quenched with high pressure water
Steel slag for port and harbor construction	2004	Sand compaction pile (SCP) material
Electric furnace oxidation slag aggregate	2005	Concrete aggregate

3.2 Law for the Recycling of Construction Materials

intense competition with other recycled materials

JISF & NSA

Develop new applications

Examples of Development of Applications for Iron/Steel Slag in New Fields

•Water/bottom muck purification materials using steel slag and granulated BF slag

Steel slag

Reduce phosphate concentration, which is cause of red tide

Fix hydrogen sulfide, which is cause of blue tide

Granulated BF slag

Prevent generation of hydrogen sulfide

•Marine environment improvement materials using **Marine Block**(carbonated steel slag block)

Marine Block

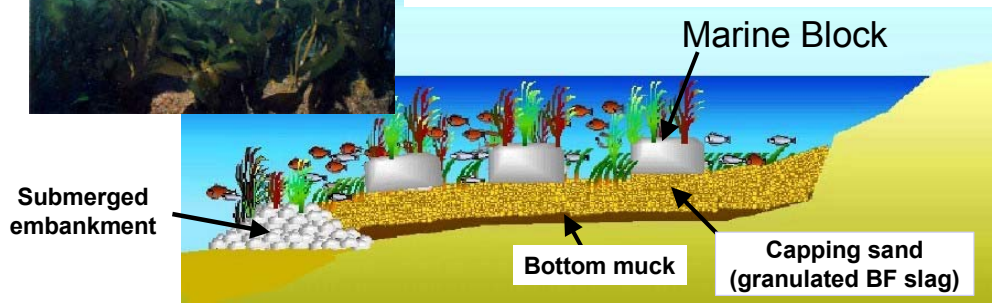
Base for large-scale seaweed cultivation

Marine environment improvement using iron and steel slag

Growth of seaweed (*Ecklonia cava*) on JFE Steel's Marine Blocks



Restoration of lost shallows and seaweed beds



1. Test project in Seto Inland Sea (started FY2001)
2. National Project in Osaka Bay (started FY2004)

3.3 Soil Contamination Countermeasures Law

Effect of recycled aggregate and cement on soil

JISF& NSA

Cooperate in establishing slag effect measurement/evaluation methods

(Establishment of environmental JIS has been completed Mar. 2005)

Safety Evaluation Method for Soil Environment

- **Evaluation values:**
  will be same as in the soil environment standard
- **Effect test method of using slag on soil:**
  evaluate slag at real size and similar condition

	Leaching standard (mg/l or less)	Content standard (mg/kg or less)
Cadmium	0.01	150
Lead	0.01	150
Hexavalent chromium	0.05	250
Arsenic	0.01	150
Total mercury	0.0005	15
Selenium	0.01	150
Fluorine	0.8	4000
Boron	1	4000

Japan - Best Available Technologies for Recycling

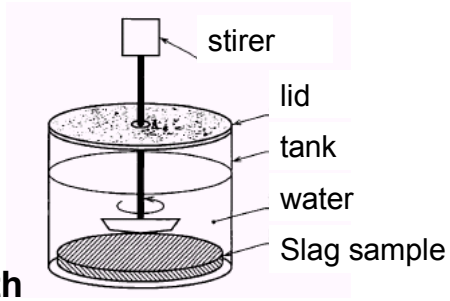
Establishment of JIS for slag environment

- **JIS K 0058, Test methods for chemicals in slags**

Leaching test
Particle size: real size or 2mm or less
Solvent L = 10x specimen kg
Stir at 200rpm x 6hr

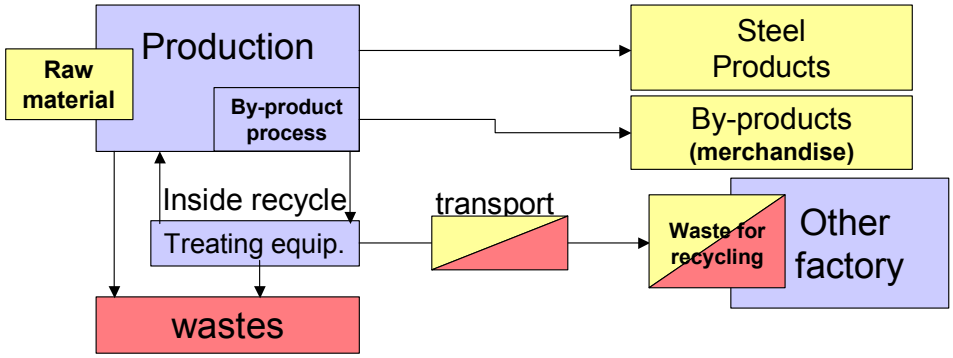
Content test
Mass accumulation ratio: 3%
Amount possible to leach with 1 mol/L of HCl
Shake 200 times/min x 2hr

Leaching tester



4. Definition for Wastes

Slag is by-product ,not waste.



Application of Public Cleaning Law (New Judgment of MOE) **Slag is under discussion**

business value	Cost	example	application of Public Cleaning Law		
			discharger	transport	receiver
sell	freight > price	waste for recycling	apply	apply	NO #
pay		waste for recycling	apply	apply	apply

with condition: 1.without toxic sub. 2.recycling business is established 3.without any extra payment 4. reasonable selection of receiver

5. Promotion to gain social understanding about slag

Position of JISF and & NSA

- Iron and Steel slag products are
  - **byproducts** of Iron and Steel production
  - variable and harmless **merchandise** which Iron and Steel makers intentionally produce and treat
  - contributing for resource saving and provision against global warming
  - promoting recycling society
- Iron and steel slag products are not wastes

7.3 Rotary Hearth Furnace Dust Recycling *Technology*

Japan - Best Available Technologies for Recycling

Advantages of Dust Recycling

1. Decreasing of Waste Emission

- Saving of waste disposal cost
- Extending landfill life

2. Recovery of Unused Resources

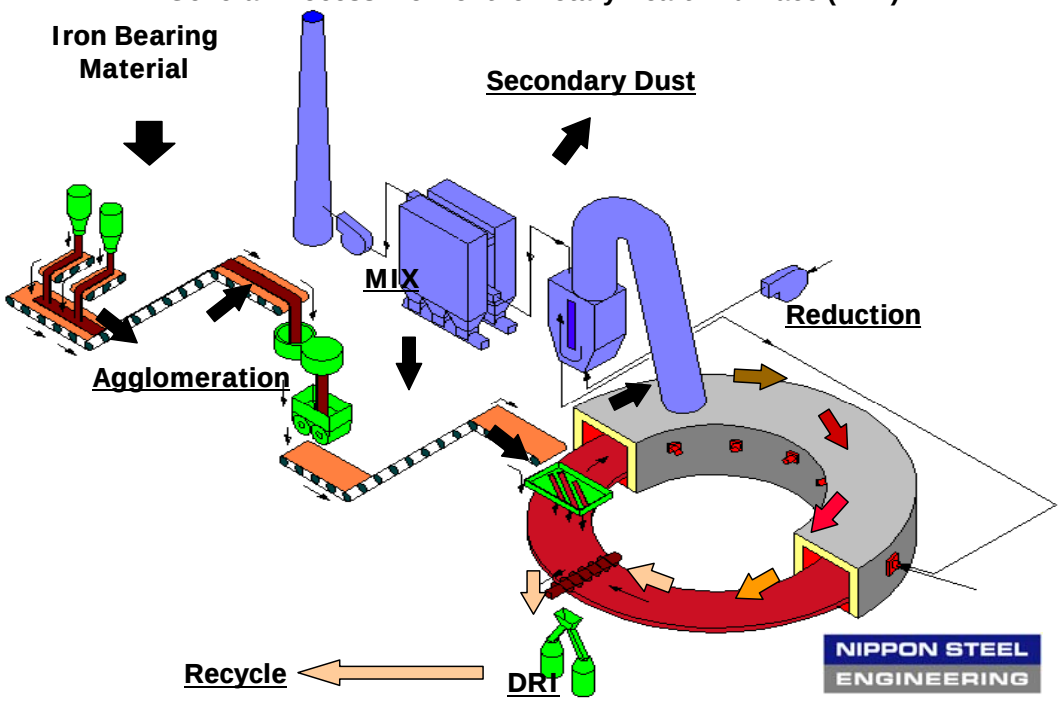
- Recycling Iron, Nickel, Zinc etc in Waste
- Utilizing carbon in waste for reduction

3. Improvement in Ironmaking Operation

- Increase in productivity
- Decrease in coke ratio by charging DRI to BF

Japan - Best Available Technologies for Recycling

General Process Flow of the Rotary Hearth Furnace (RHF)



Ideal Process for Dust Recycling

Various Limitations for Recycling

↓

Impurity Elimination & Fe Metallization

Instability of Dust Properties

↓

Dust Blending Techniques

And Good Cost-Performance

NIPPON STEEL ENGINEERING

Japan - Best Available Technologies for Recycling

DUST RECYCLING TECHNOLOGIES

Basic Planning of Waste Recycling System

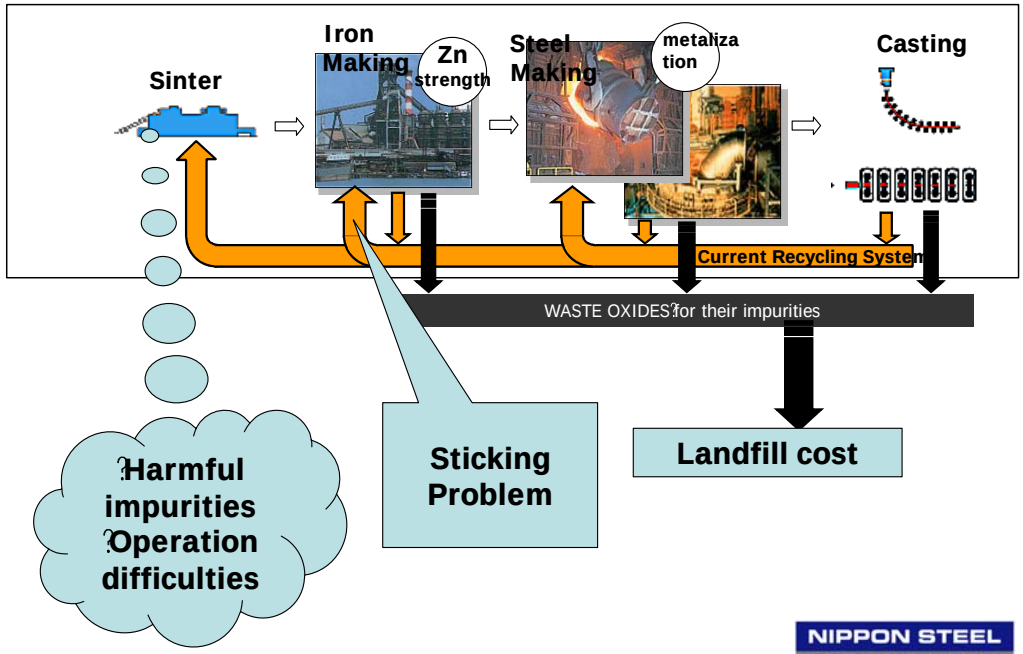
Selection of Pre-treatment Process of Dust

Configuration of Total System of RHF Plant

Efficient Operation

Japan - Best Available Technologies for Recycling

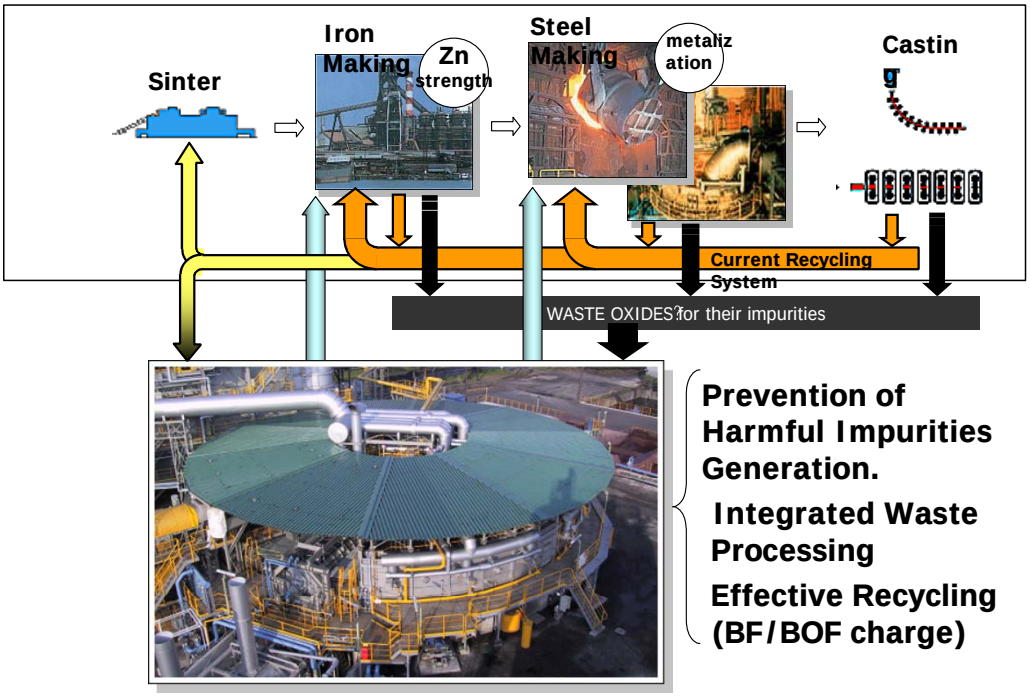
BEST SOLUTION FOR DUST RECYCLING



NIPPON STEEL ENGINEERING

Japan - Best Available Technologies for Recycling

BEST SOLUTION FOR DUST RECYCLING



Prevention of Harmful Impurities Generation.

Integrated Waste Processing

Effective Recycling (BF/BOF charge)

DUST RECYCLING TECHNOLOGIES

Basic Planning of Waste Recycling System

Selection of Pre-treatment Process of Dust

Configuration of Total System of RHF Plant

Efficient Operation



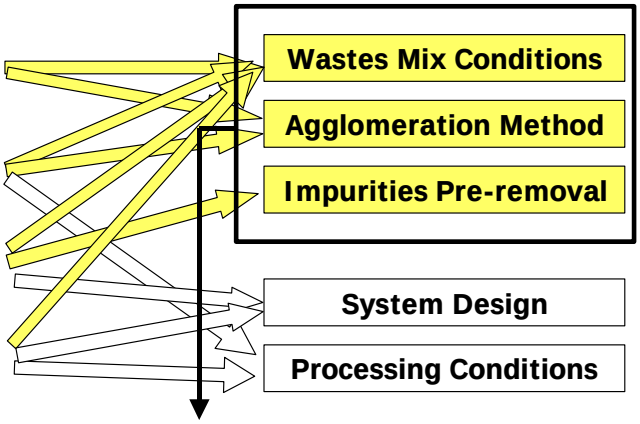
MUCH KINDS OF MATERIAL PROCESSING

For Stable Agglomeration

For Keeping DRI Qualities

For Prevention of Harmful Impurities Generation

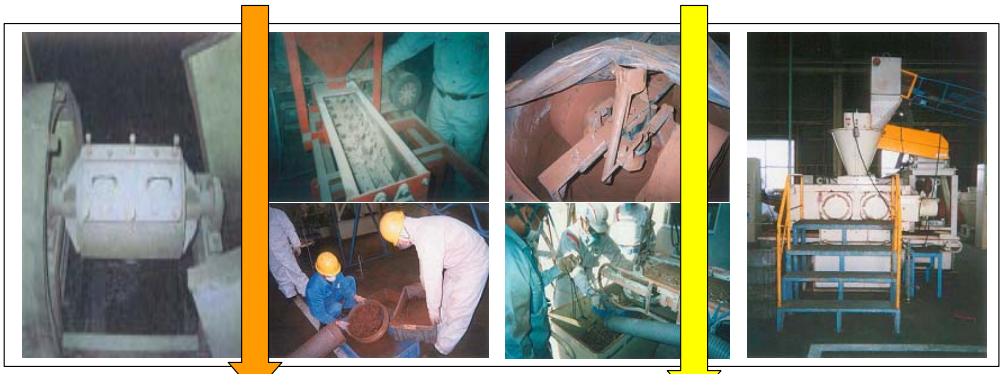
For Stable Reduction



Pre-treatment Process of Dust&Sludge Has First Priority

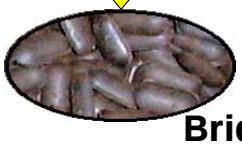
Selection of Pre-treatment Process of Dust

Drying, Mixing, and Agglomeration Engineering Using Accumulated Data Base (Depend on the Property of Dust)





Pellet



Briquette

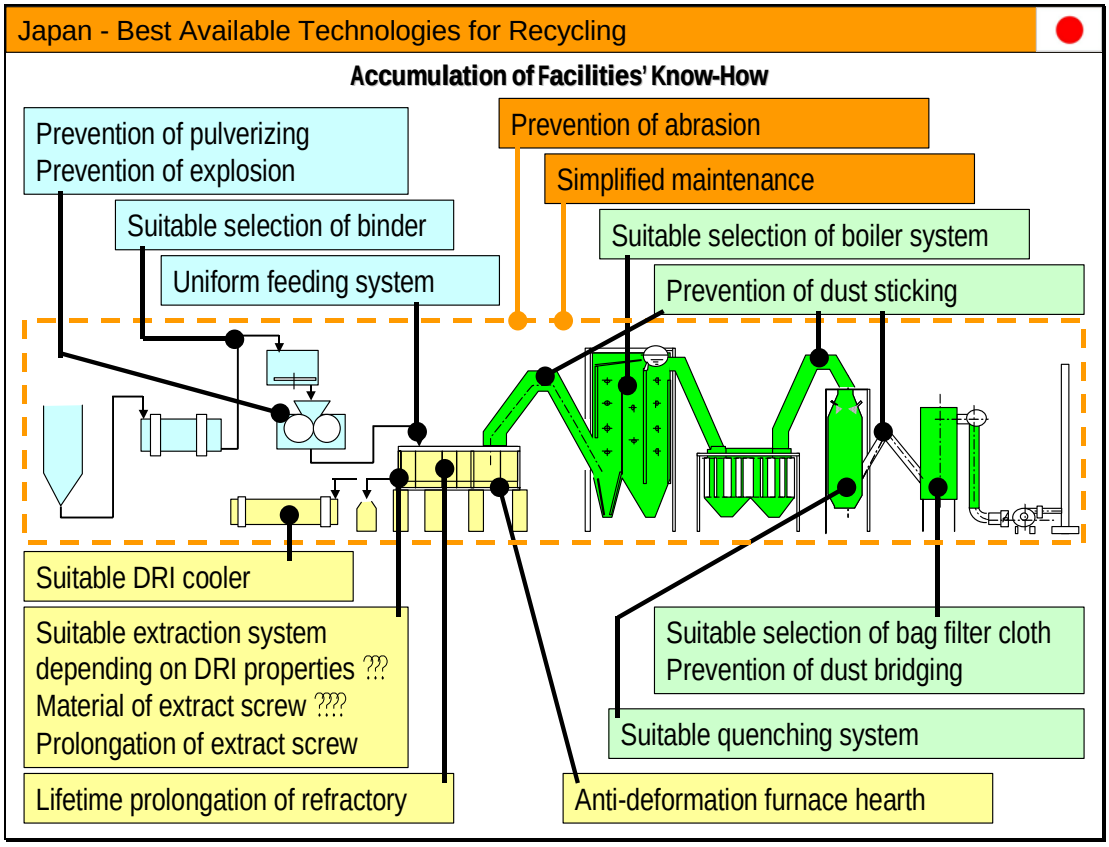
DUST RECYCLING TECHNOLOGIES

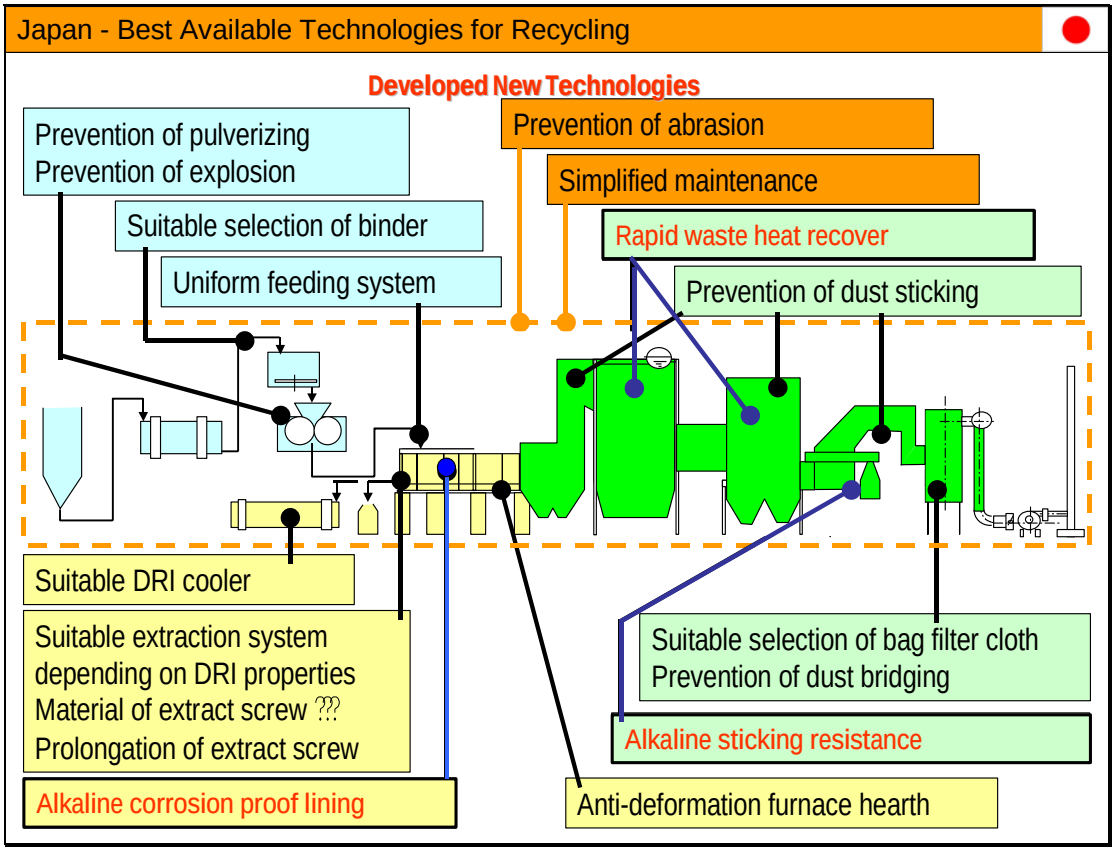
Basic Planning of Waste Recycling System

Selection of Pre-treatment Process of Dust

Configuration of Total System of RHF Plant

Efficient Operation


Japan - Best Available Technologies for Recycling
Accumulation of Facilities' Know-How
Prevention of pulverizing
Prevention of explosion
Prevention of abrasion
Simplified maintenance
Suitable selection of binder
Suitable selection of boiler system
Uniform feeding system
Prevention of dust sticking
Suitable DRI cooler
Suitable extraction system
depending on DRI properties ???
Material of extract screw ????
Prolongation of extract screw
Suitable selection of bag filter cloth
Prevention of dust bridging
Suitable quenching system
Lifetime prolongation of refractory
Anti-deformation furnace hearth


Japan - Best Available Technologies for Recycling
Developed New Technologies
Prevention of pulverizing
Prevention of explosion
Prevention of abrasion
Simplified maintenance
Suitable selection of binder
Rapid waste heat recover
Uniform feeding system
Prevention of dust sticking
Suitable DRI cooler
Suitable extraction system
depending on DRI properties
Material of extract screw ???
Prolongation of extract screw
Suitable selection of bag filter cloth
Prevention of dust bridging
Alkaline sticking resistance
Alkaline corrosion proof lining
Anti-deformation furnace hearth

DUST RECYCLING TECHNOLOGIES

Basic Planning of Waste Recycling System

Selection of Pre-treatment Process of Dust

Configuration of Total System of RHF Plant

Efficient Operation

Japan - Best Available Technologies for Recycling

RHF Supply Record

Customer	Start up	Capacity t/yr	Material	DRI recycling
NSSC HIKARI	May-01	30,000	Stainless dust and sludge	EAF
Nippon Steel Kimitsu	Dec-02	135,000	BF & BOF sludge etc.	Blast Furnace
Asahi Kyogyo	Jun-07	10,000	EAF dust	EAF
China Steel	Dec-07	130,000	BF & BOF sludge etc.	Blast Furnace
Nippon Steel Kimitsu	Mar-08	310,000	BF & BOF dust etc.	Blast Furnace

Japan - Best Available Technologies for Recycling

Outline of RHF in Hikari Works



Capacity	60,000 wet-t/y
	30,000 dry-t/y
Outer diameter of furnace	Approx. 15 m
Processing time	Approx. 15 min
Material (Stainless Dust and Sludge)	EAF dust
	Scale with high water content (water content : 90%)
Usage of DRI	EAF

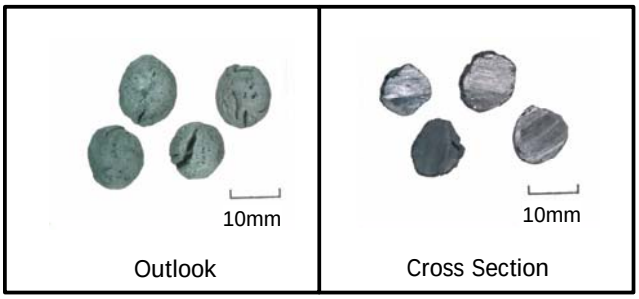
Japan - Best Available Technologies for Recycling

Outline of RHF in Kimitsu Works

Capacity	135,000 dry-t/y
Outer diameter of furnace	Approx. 24 m
Material	Wet sludge from BF
	Wet sludge from BOF
	Wet sludge from pickling line
	Wet sludge from mill
	Other dust
Treatment process	**Agglomeration** ? RHF ? **BF**

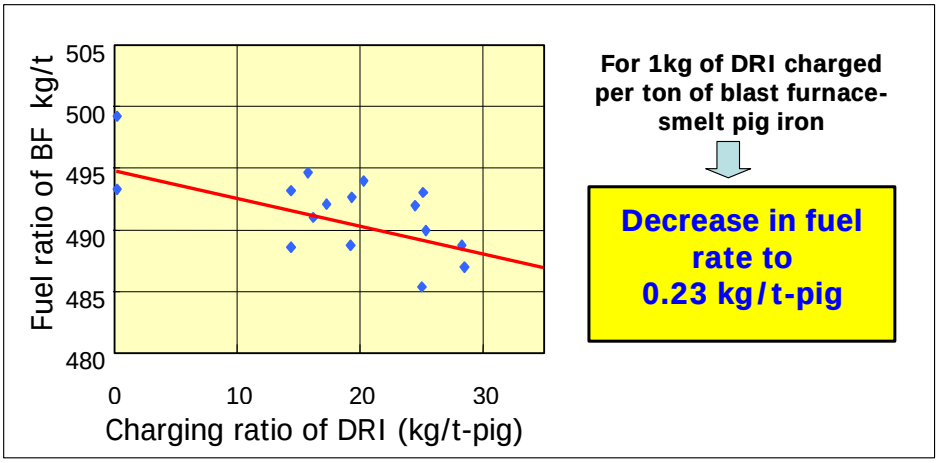
RHF-BF Combination

DRI Pellets Made by the RHF



Metallic color
Well sintered structure

Improvement in Iron-making Operation at KIMITSU



Increase in Productivity or Decrease in Fuel Ratio of BF

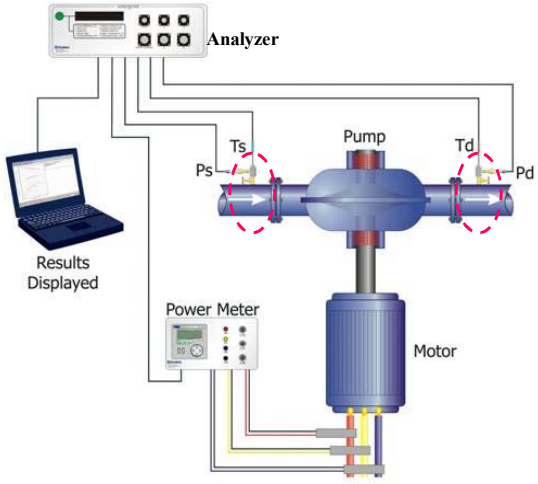
8.1 Auditing Rotary Machines for Pump Efficiency

Korea - Best Available Technologies for Common Systems

3. Auditing Rotatory Machines in POSCO

3.1 Auditing Methodology for pump efficiency

- Measure temperature and pressure of the fluid.
- ESCO-PRO(POSCO venture company) developed the technology.





Temp/Press

- **Ts : Inlet Temp.**
- **Ps : Inlet Press.**
- **Td : Outlet Temp.**
- **Pd : Outlet Temp.**

Korea - Best Available Technologies for Common Systems

3.2 Energy Saving Effect

(GW) 1 Hot Strip Mill Pump: 2003.7.~2004.6

	Before	After	MEMO
Pump	3,400kW x 2EA (Fluid Coupling) + 2,000kW x 4?		
Operation	3,400kW 2 EA + 2,000 kW 1 EA	3,400 kW 2 EA	Energy Saving 34%
Power	3,230kW	2,122kW	65 thous. $/year

(PW) 2 Hot Strip Mill Pump: 2004.11.~12

	Before	After	MEMO
Pump	3,100kW x 2EA (Fluid Coupling) + 2,900kW x 3?		
Operation	3,100kW 1 EA + 2,000 kW 0~2 EA	3,100kW 1~2 EA + 2,000 kW 0~1 EA	Energy Saving 22%
Power	6,700 kW	5,200 kW	63 thous. $/year

8.2 AIRMaster+ Software Tool

United States - Best Available Technologies Common Systems

AIRMaster+ Software Tool

Improved Compressed Air System Performance

AirMaster+ models the supply side of a compressed air system to identify efficiency improvement opportunities.

Using plant-specific data, the free software tool evaluates operational costs for various compressed air equipment configurations and system profiles. It provides estimates of potential savings gained from selected energy efficiency measures and calculates the associated simple payback periods.

AIRMaster+ includes a database of industry-standard compressors and creates an inventory specific to the actual air compressors onsite based on user input. The software simulates existing and modified compressed air system operations. It can model part-load system functions for an unlimited number of rotary screw, reciprocating, and centrifugal air compressors operating simultaneously with independent control strategies and schedules.

AIRMaster+ evaluates the energy savings potential of the following energy efficiency actions:

- Reducing air leaks
- Improving end-use efficiency
- Reducing system air pressure
- Using unloading controls
- Adjusting cascading set points
- Using an automatic sequencer
- Reducing run-time
- Adding a primary receiver volume

AIRMaster+ facilitates:

- Development of 24-hour metered airflow or power data load profiles for each compressor
- Calculation of life-cycle costs
- Input of seasonal electrical energy and demand charges
- Tracking of maintenance histories for systems and components



Compressed Air Unit

Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.3 Combined Heat and Power (CHP) Tool

United States - Best Available Technologies Common Systems

Combined Heat and Power (CHP) Tool

Improved Overall Plant Efficiency and Fuel Use

The Combined Heat and Power (CHP) tool identifies opportunities for application of CHP systems to reuse waste heat and determines optimal equipment size, implementation costs, and the payback period for investing in CHP technologies.

The tool can be used to size or select design parameters for a new CHP system or to optimize a system in use. Site-specific data can be entered into the tool or default settings from the tool's database can be used to generate:

- Current energy use and performance data for selected furnaces/boilers and turbines
- Energy use data for a CHP system
- Estimated energy savings
- Cost details for implementing a CHP system
- Payback period based on cost data provided for the fuel, electricity, and equipment used in a CHP system

Click here for more information and to download the free software

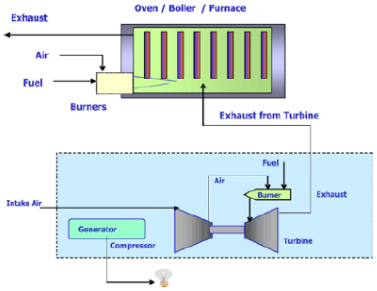
Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

The CHP Tool evaluates the feasibility of using gas turbines to generate power and using the turbine exhaust gases to supply heat to industrial heating systems. Analysis is provided for three commonly used systems:

Fluid Heating in Fired Heat Exchangers – Exhaust gases from a gas turbine are used to supply heat for indirect heating of liquids or gases in heat exchangers.

Exhaust Gas Heat Recovery in Heaters – Direct heating application where turbine exhaust gases are mixed or injected in a furnace, oven, heater, dryer or heat recovery steam generator (HRSG), or boiler to supply all or partial heating requirements.

Duct Burner Systems – A duct burner is used to consume residual oxygen from turbine exhaust gases for fuel combustion (natural gas, light oil, by-product gases).



Example CHP application – exhaust gases from a turbine is used to heat fluids in a heat exchanger.

8.4 Fan System Assessment Tool (FSAT)

United States - Best Available Technologies Common Systems

Fan System Assessment Tool (FSAT)

Efficiency Enhancement for Industrial Fan Systems

The Fan System Assessment Tool (FSAT) quantifies energy consumption and energy savings opportunities in industrial fan systems, helping users understand how well their fan systems are operating and determine the economic benefit of system modifications.

FSAT allows users to input information about their fans and motors and calculates the energy used by the fan system and the overall system efficiency. It approximates potential energy and cost savings and helps determine which options are most economically viable when multiple opportunities exist.

Capabilities:

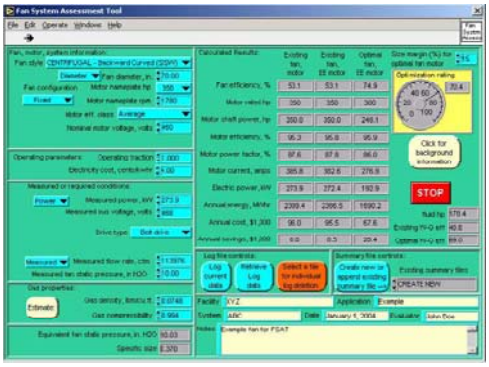
- Determine fan system efficiency
- Identify degraded fans
- Collect data for trending system operation
- Quantify potential cost and energy savings for various operating configurations

Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

Performance Measurement:
FSAT helps users calculate differences between rated and installed performance due to issues such as:

- High duct velocity
- Discharge dampers locked in position
- Obstructed inlets
- Incorrectly sized fans
- Poor duct geometry
- Degraded impellers



FSAT main data input screen

8.5 MotorMaster+ International

United States - Best Available Technologies Common Systems

MotorMaster+ International

Cost-Effective Motor System Efficiency Improvement

MotorMaster+ International helps plants manage their motor inventory and make cost-effective decisions when repairing and replacing motor systems.

Based on site-specific user input and database information for typical motor functionality, the tool determines energy and cost savings for motor selection decisions by taking into account variables such as motor efficiency at its load point, purchase price, energy costs, operating hours, load factor, and utility rebates.

Analysis features allow for the selection of the best available motor for a given application, with the determination of demand reductions, greenhouse gas emission reductions, simple payback, cash flows, and after-tax rate of return on investment.

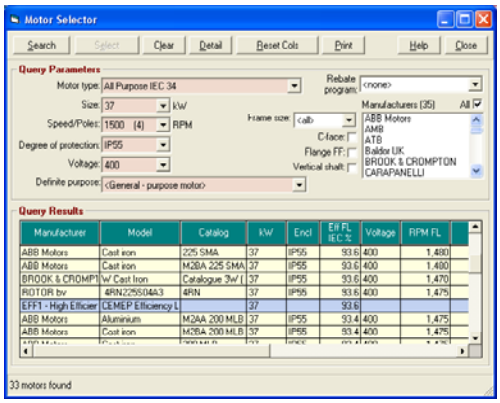
MotorMaster+ International allows the user to conduct economic analyses using various currencies and to insert applicable country or regional motor full-load minimum efficiency standards, and country-specific motor repair and installation cost defaults.

Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

Software contains comprehensive database:

- Available data for both 60 Hz National Electrical Manufacturers Association (NEMA) and 50 Hz metric or International Electrotechnical Commission (IEC) motors
- Over 25,000 NEMA motors and over 7,200 IEC motors
- Ability to modify motor operating details in the database



Screen shot of MotorMaster+ International interface

8.6 NO_X and Energy Assessment Tool (N_XEAT)

United States - Best Available Technologies Common Systems

NOx and Energy Assessment Tool (NxEAT)

Reduced NOx Emissions and Improved Energy Efficiency

The NOx and Energy Assessment Tool (NxEAT) provides a systematic approach to estimate NOx emissions and analyze NOx and energy reduction methods and technologies.

NxEAT allows plants to analyze the effects of NOx reduction methods and energy efficiency practices by providing equipment inventory and configuration information. The tool targets specific systems such as fired heaters, boilers, gas turbines, and reciprocating engines to help identify the NOx and energy savings potential associated with each option. The tool also provides calculators that aid in comparisons between options.

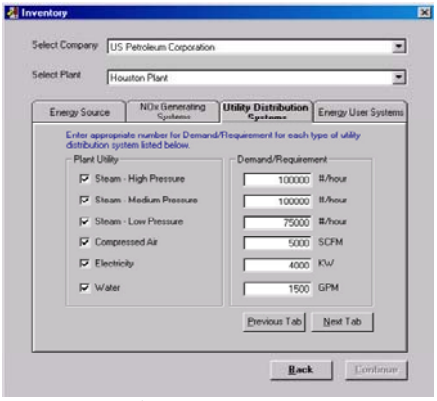
Based on inputted plant-specific information and the NxEAT database, the tool creates a report presenting estimated NOx reduction, energy savings, and costs.

Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

NxEAT Output:

- Profile of the plant's current NOx emissions, energy use, and annual energy cost for NOx-generating equipment
- Energy savings analysis
- Calculations and comparisons of NOx emission and capital reduction for each analysis
- Tables and charts of NOx and energy savings



NxEAT Screen Shot

8.7 Process Heating Assessment and Survey Tool

United States - Best Available Technologies Common Systems

Process Heating Assessment and Survey Tool

Identify Heat Efficiency Improvement Opportunities

The Process Heating Assessment and Survey Tool (PHAST) identifies ways to increase energy efficiency by surveying all process heating equipment within a facility, determining the equipment that use the most energy, and evaluating energy use under various operating scenarios.

Based on user input guided by the tool and a database of thermal properties, PHAST calculates energy use in specific pieces of equipment and throughout the process heating system. The output facilitates the identification and prioritization of efficiency improvements by suggesting methods to save energy in each area where energy is used or wasted, and by offering a listing of additional resources.

Capabilities:

Calculation of potential savings – Based on user-supplied equipment parameters, PHAST can compare the energy performance of individual pieces of equipment under various operating conditions and "what-if" scenarios, such as applying various energy-saving measures.

Comprehensive equipment survey – PHAST surveys all equipment that use fuel, steam, or electricity for heating. Based on facility-specific heat input and furnace operating data, PHAST reports annual fuel, electricity, and steam consumption of each piece of equipment, in addition to estimated annual energy costs. Efficiency improvements can therefore focus on equipment that use the most energy.

Determination of wasted energy – PHAST constructs a detailed heat balance for selected pieces of process heating equipment, considering all areas of the equipment in which energy is used, lost, or wasted. The heat balance calculations pinpoint areas of the equipment where energy is wasted or used unproductively.

Steel Reheating Furnace Example

At one steel mill, PHAST identified significant potential savings in a steel reheating furnace. The furnace had a firing capacity of 135 million (MM) Btu per hour for the heating zone and 32MM Btu per hour for the soak zone. PHAST indicated that the furnace's fuel use could be reduced by approximately 30MM Btu per hour for the heating zone and 5MM Btu per hour for the soak zone. Another 2MM Btu per hour could be saved by reducing losses through openings. Total potential savings identified for the unit were 37MM Btu per hour, or 22% of all energy used by the furnace.

Suggested low-cost improvements included better control of the air-fuel ratio and installation of radiation shields (curtains that eliminate radiation heat loss).

Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.8 Quick Plant Energy Profiler (Quick PEP)

United States - Best Available Technologies Common Systems

Quick Plant Energy Profiler (Quick PEP)

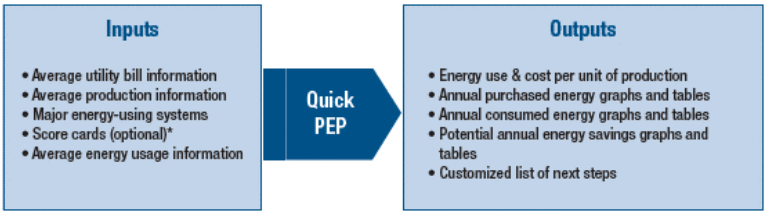
First Step to Identify Opportunities for Energy Savings

Quick PEP, a free online software tool, helps facilities quickly diagnose their energy use and begin identifying opportunities for savings.

QuickPEP uses basic information about major energy-consuming systems to create a report that profiles plant energy usage. The tool's output presents the energy usage for plant processes and identifies specific, targeted ways to economically save energy and help reduce environmental emissions associated with energy production and use.

Software Capabilities

- Details plant energy consumption
- Provides an overview of energy generation, purchases, and associated costs
- Describes potential energy and cost savings
- Offers customized list of suggested 'next steps' to begin implementing energy-saving measures



Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.9 Steam System Tools

United States - Best Available Technologies Common Systems

Steam System Tools

Tools to Boost Steam System Efficiency

A suite of software tools help enable facilities to evaluate steam systems and to identify opportunities for improvement.

Steam System Scoping Tool

- Quickly evaluates the plant's entire steam system and spots areas that are the best opportunities for improvement, suggesting various methods to save steam energy and boost productivity
- Profiles and grades steam system operations and management from user-inputted steam system operating practices, boiler plant operating practices, and distribution and recovery practices
- Compares steam system operations against identified best practices

3E Plus

- Calculates the most economical thickness of industrial insulation for user-inputted operating conditions in order to conserve energy and avoid over-insulation expenses
- Users can utilize built-in thermal performance relationships of generic insulation materials or supply conductivity data for other materials

Steam System Assessment Tool

- Develops approximate models of real steam systems to quantify the magnitude (energy, cost, and emission savings) of key potential steam improvement opportunities
- Contains all the key features of typical steam systems – boilers, backpressure turbines, condensing turbines, deaerators, letdowns, flash vessels, and feed water heat exchangers
- Analyzes boiler efficiency, boiler blowdown, cogeneration, steam cost, condensate recovery, heat recovery, vent steam, insulation efficiency, alternative fuels, backpressure turbines, steam traps, steam quality, and steam leaks
- Features include a steam demand savings project, a user-defined fuel model, a boiler stack loss worksheet for fuels, and a boiler flash steam recovery model

Click here for more information and to download the free software

Source
Industrial Technologies Program fact sheet
http://www1.eere.energy.gov/industry/bestpractices/software.html

8.11 Regenerative Burner

Application of Regenerative Burners to Iron and Steel Processes

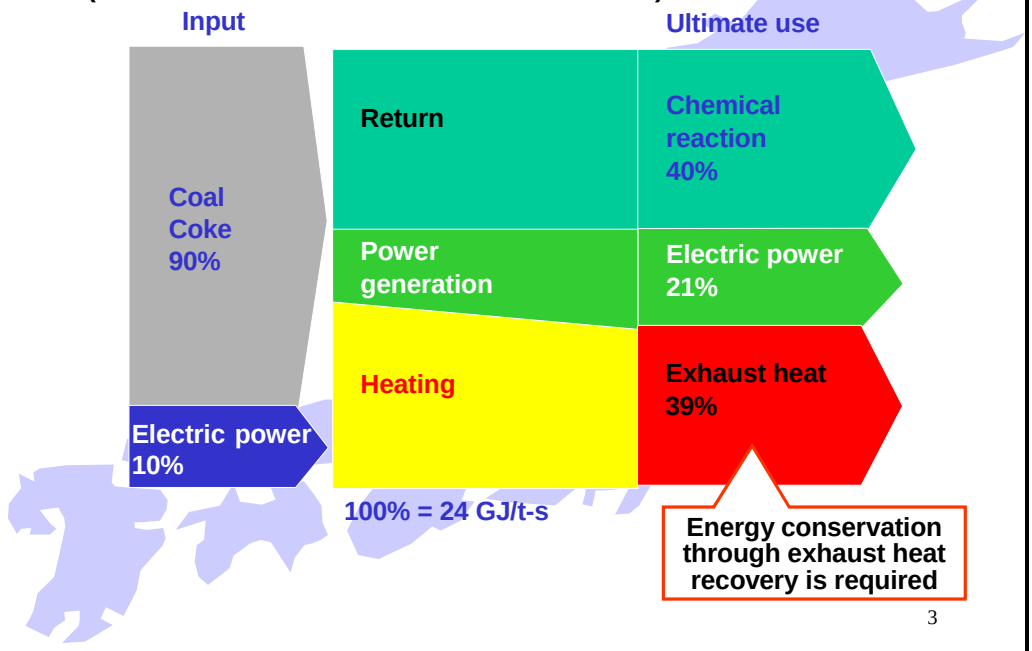
Japan Iron and Steel Federation

Contents

1. **Energy Balance of Iron Works**
2. **Heat Recovery Technology for Heating Furnaces**
   - (1) Conventional heat Recovery Technologies
   - (2) Heat recovery technologies using regenerative burners
   - (3) Development issues and expected effects of regenerative burners
3. **Basic Technology of Regenerative Burners**
   - (1) Optimization technology for regenerators
   - (2) Low-NOx combustion technology
4. **Adoption of Regenerative Burners**
   - (1) Development and history of adoption
   - (2) Transition of introduction of high-performance industrial furnaces
   - (3) Introduction of high-performance industrial furnaces by furnace type
5. **Application Examples for Regenerative Burners**
   - (1) Application to iron and steel processes
   - (2) Application example 1: Continuous reheating furnace
   - (3) Application example 2: Batch reheating furnace
   - (4) Application example 3: Pot heating
   - (5) Application example 4: Partial application to a reheating furnace
   - (6) Application example 5: Forging furnace
   - (7) Application example 6: Heat treatment furnace
   - (8) Application example 7: Melting furnace
   - (9) Effect of the introduction of high-performance industrial furnaces
   - (10) Maintenance of regenerative burners
6. **Summary**

1. Energy Balance of Iron Works

(Iron works of a class of 8 million t crude steel)

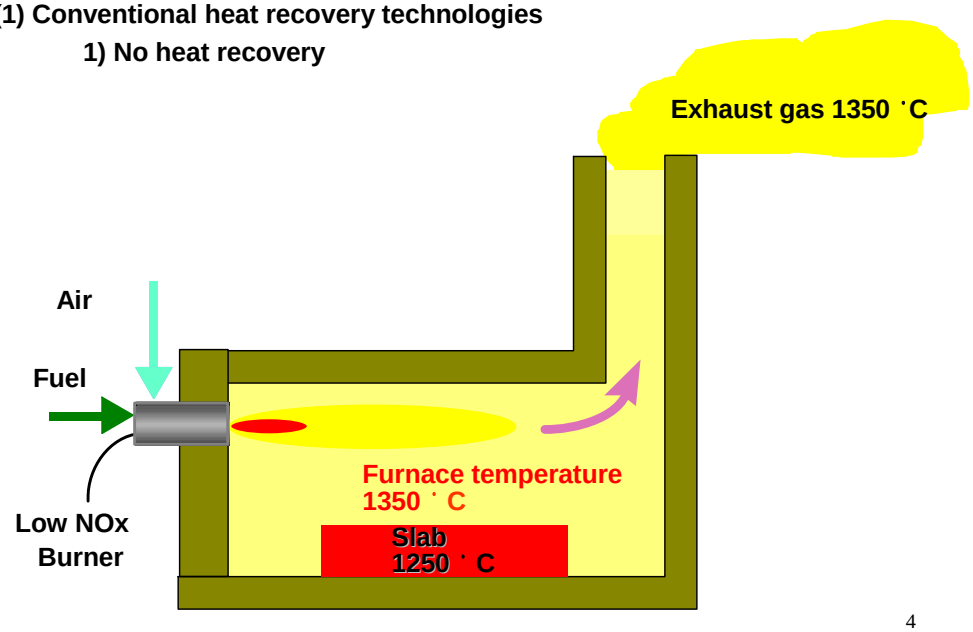


3

2. Heat Recovery Technology for Reheating Furnaces

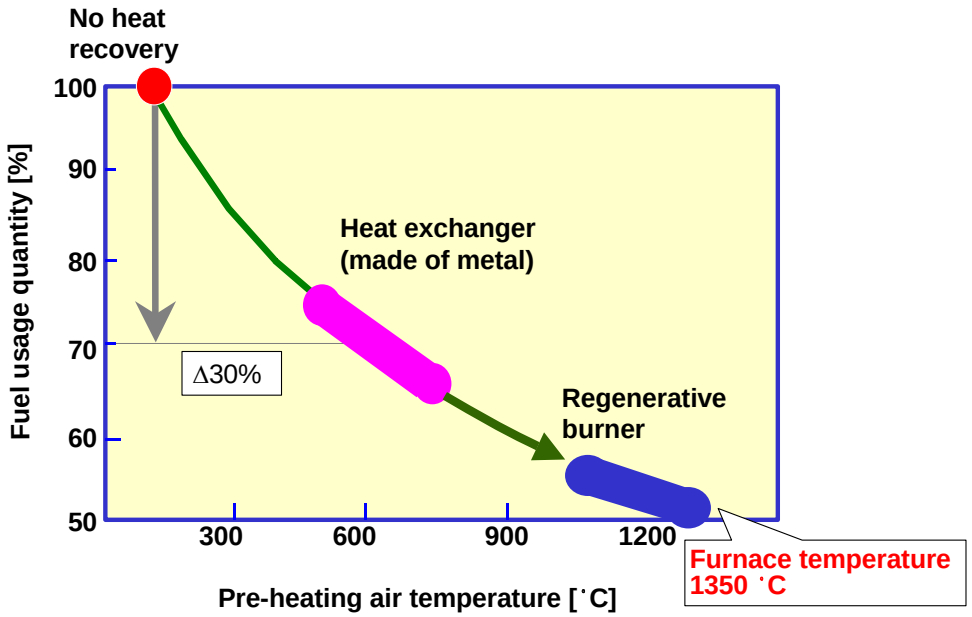
(1) Conventional heat recovery technologies

1) No heat recovery



4

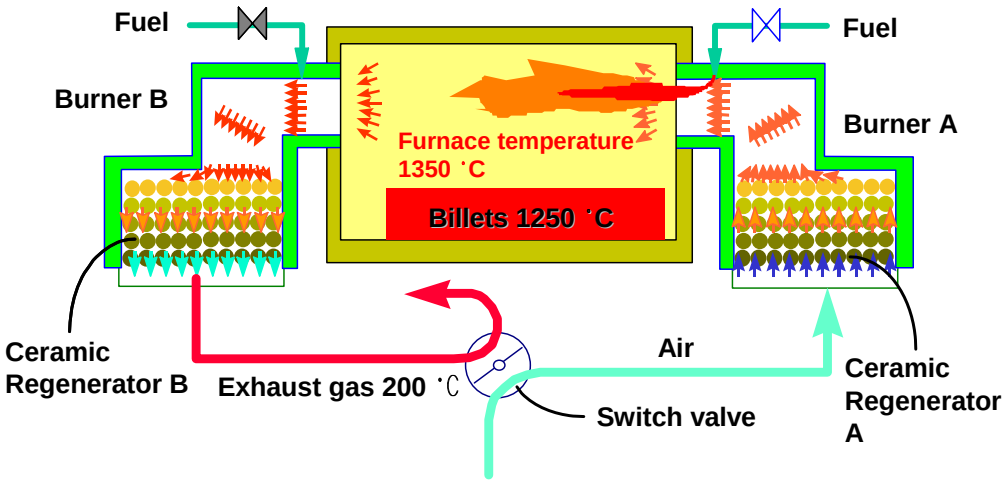
3) Comparison of fuel usage quantities



6

(2) Heat recovery technologies using regenerative burners

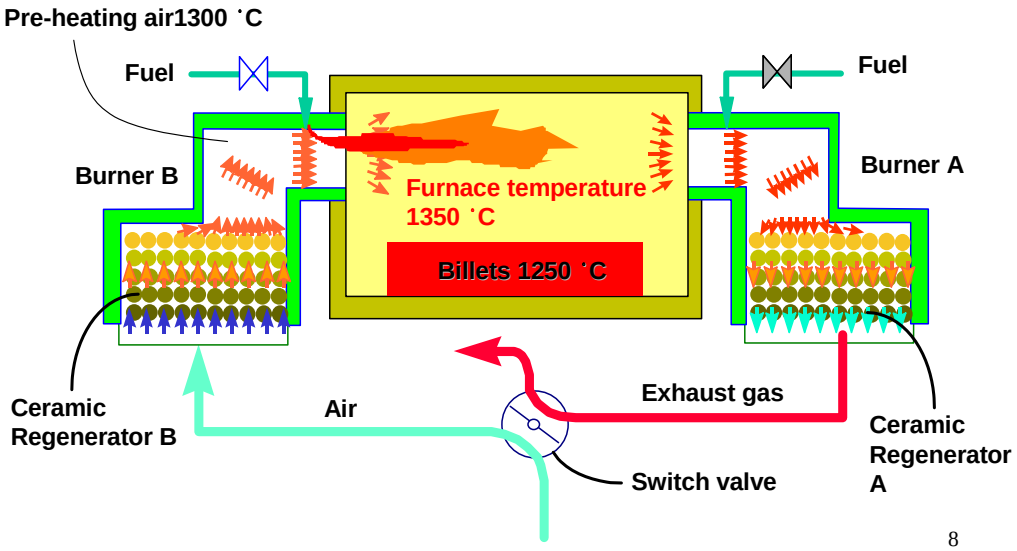
1) Principle of operation



7

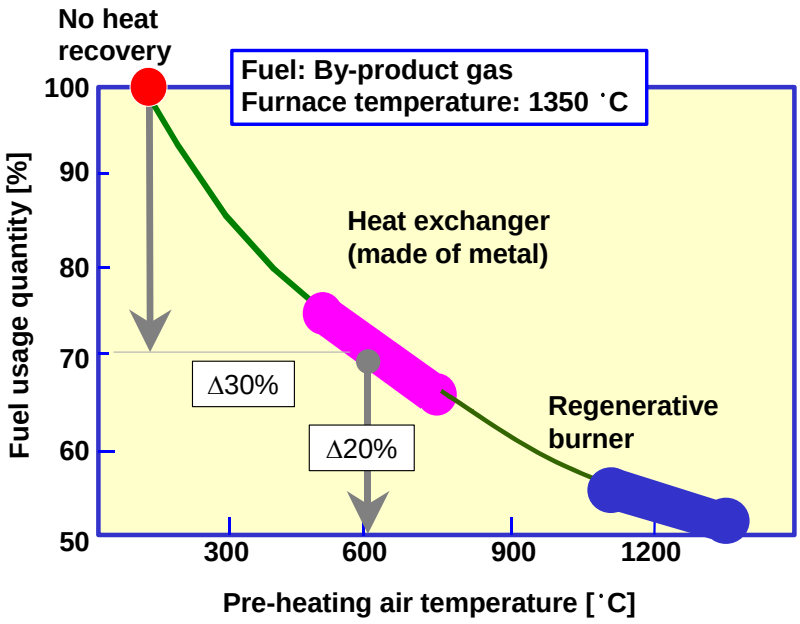
(2) Heat recovery technologies using regenerative burners

1) Principle of operation



8

2) Comparison of fuel usage quantities



9

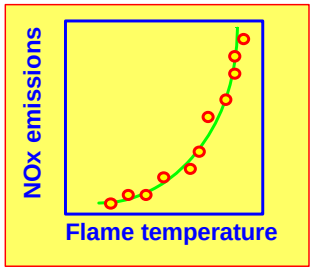
(3) Issues and expected effects of regenerative burners

Issue 1)
Regenerator optimization technology

→ **Expected effect 1)**
Energy conservation (Highly efficient heat recovery)

Rise of pre-heating air temperature

Increase of NOx (damaging the environment)



Issue 2)
Low-NOx combustion technology

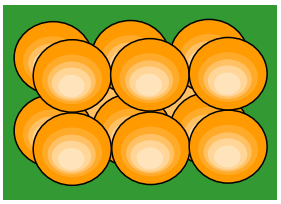
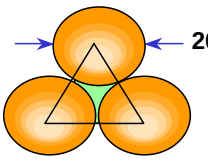
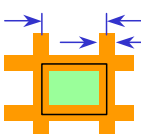
→ **Expected effect 2)**
Cleaner exhaust gas

Issue 3) Improved reliability of switch valve / control system

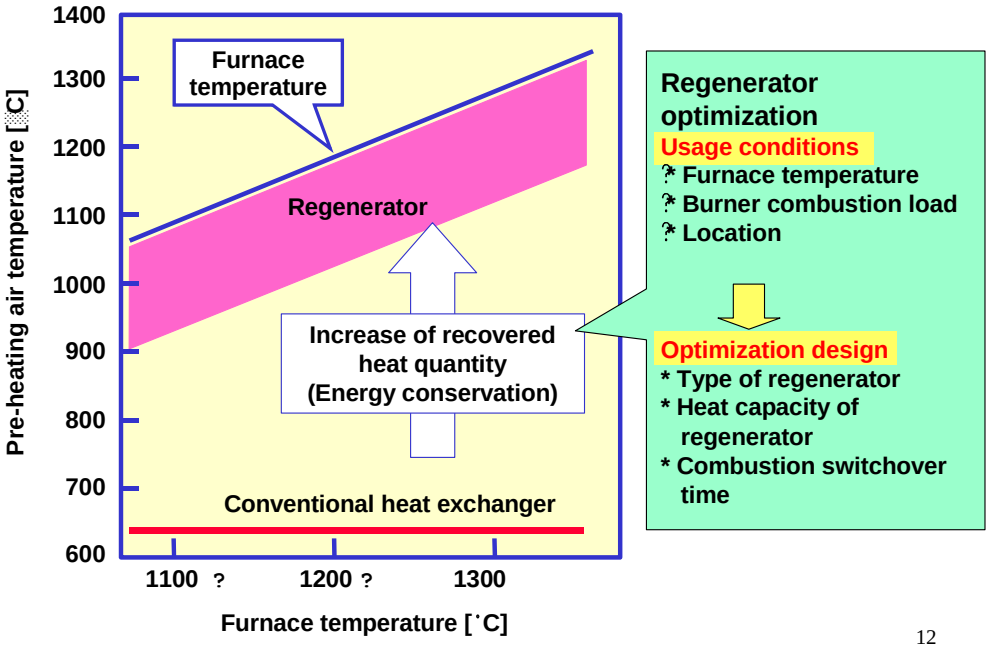
3. Basic Technology of Regenerative Burners

(1) Regenerator optimization technology

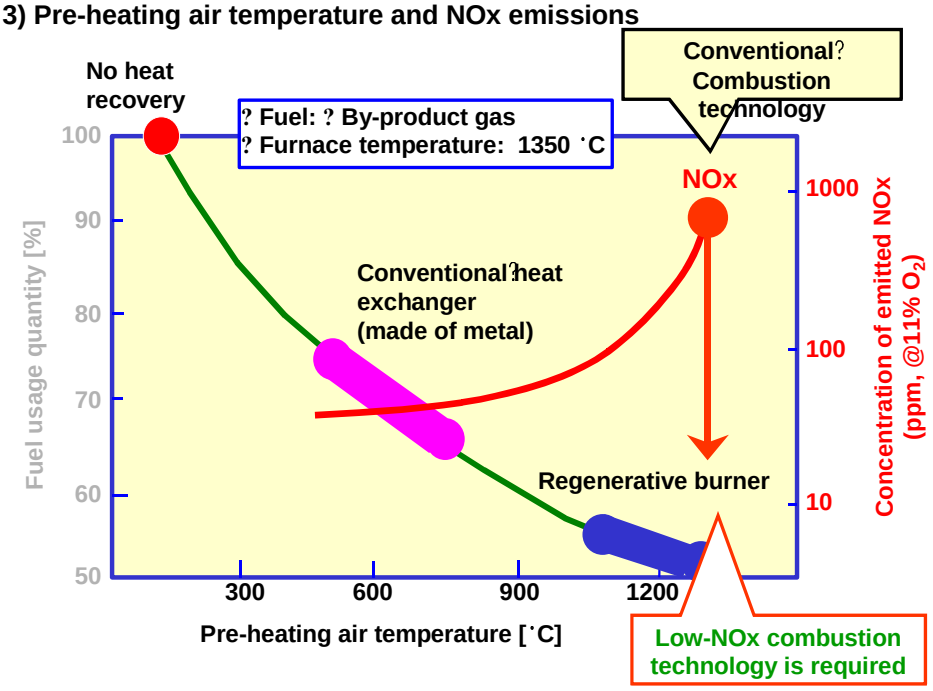
1) Types of regenerator

	Balls	Honeycomb
		
		
Area/surface ratio	240 m^2/m^3	1340 m^2/m^3
Aperture ratio	9%	71%
Weight	15	1?

2) Rise of pre-heating air temperature through regenerator optimization

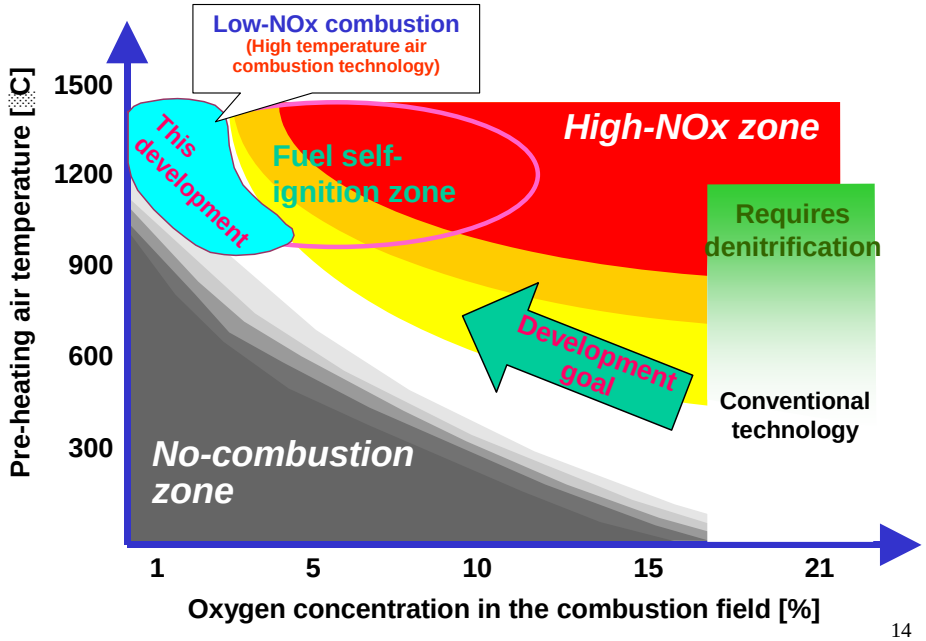


3) Pre-heating air temperature and NOx emissions



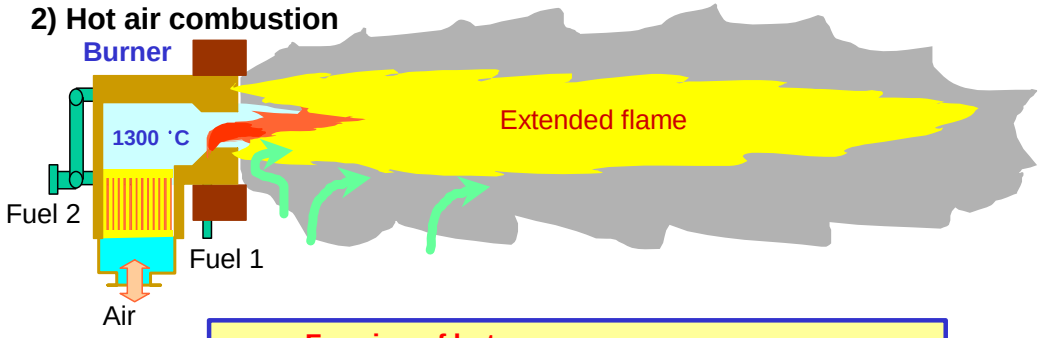
(2) Low-NOx combustion technology

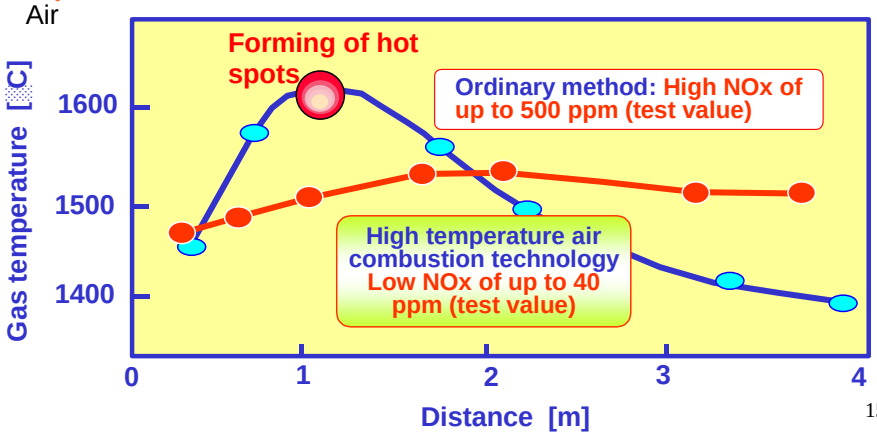
1) Basic concept of low-NOx combustion



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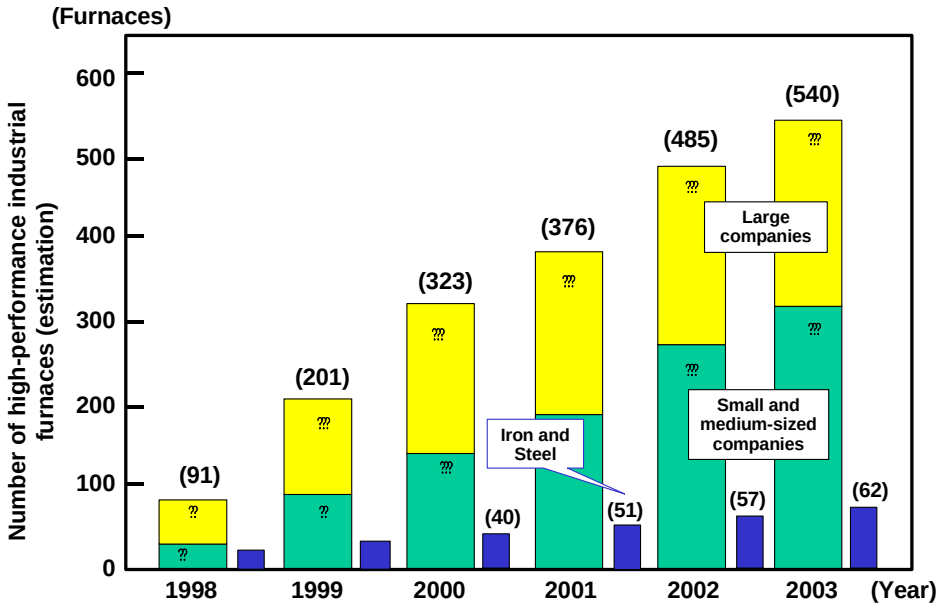
2) Hot air combustion





15

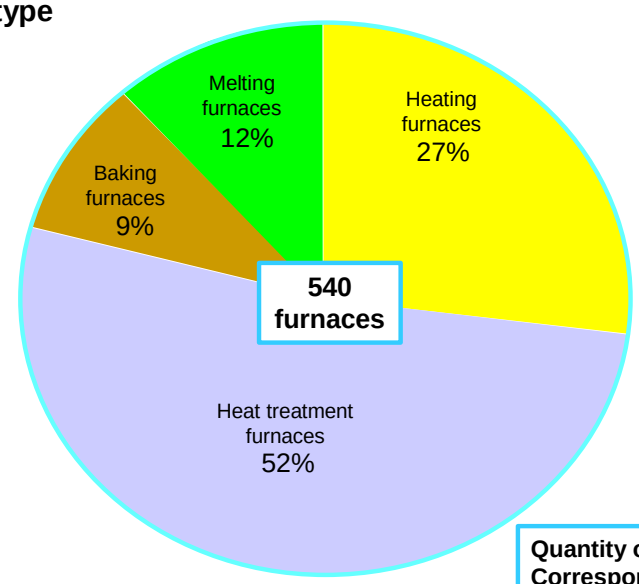
(2) Transition of the introduction of high-performance industrial furnaces



(Source: Kogyo Kanetsu, Vol. 41, No. 4, p. 19, 2004.7)

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(3) Introduction of high-performance industrial furnaces by furnace type



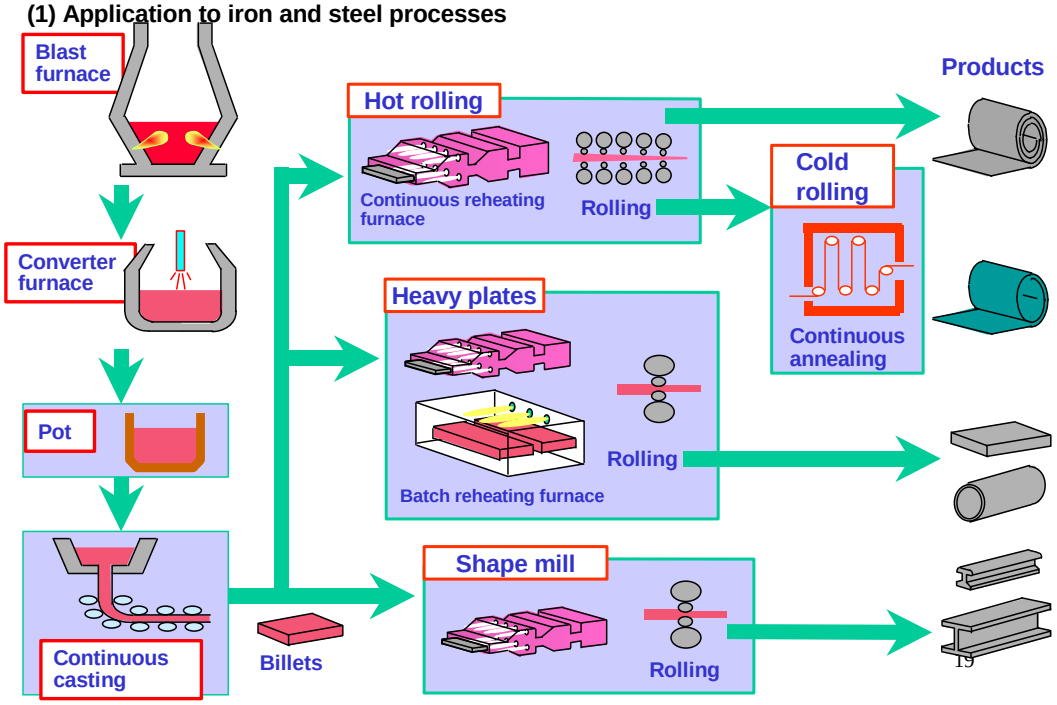
Quantity of saved energy Corresponding to 400,000 kl/year of crude oil

(Source: Kogyo Kanetsu, Vol. 41, No. 4, p. 19, 2004.7)

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5. Application Examples for Regenerative Burners

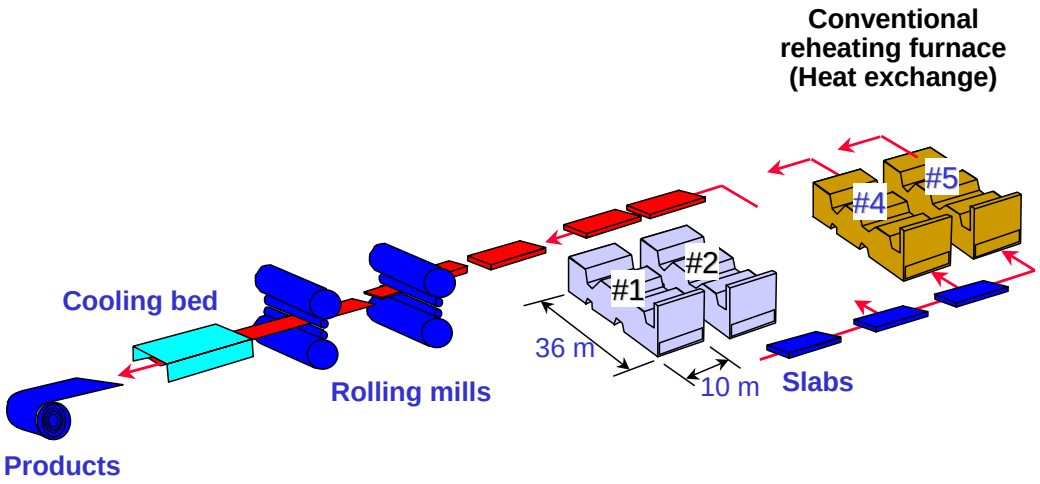
(1) Application to iron and steel processes



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(2) Application example 1: Continuous reheating furnace

1) Before remodeling



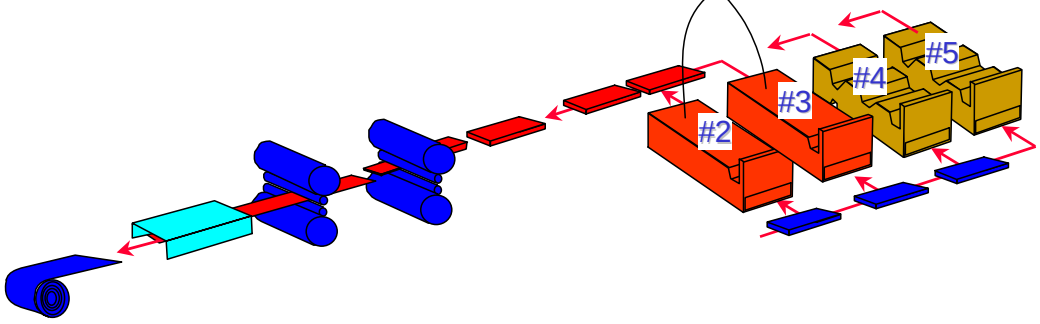
20

2) After remodeling

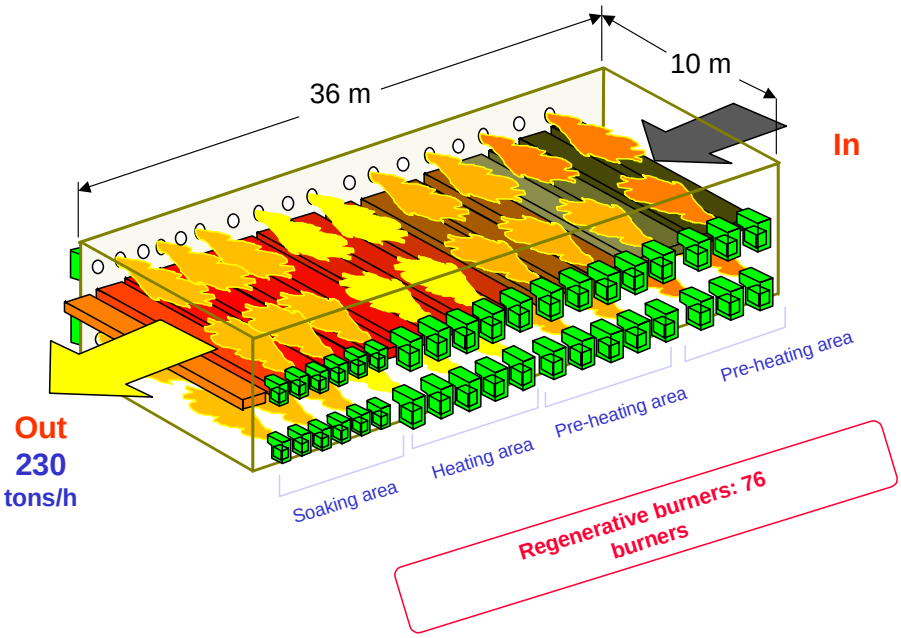
- Energy conservation
- Low NOx

Regenerative burner furnace#2, #3

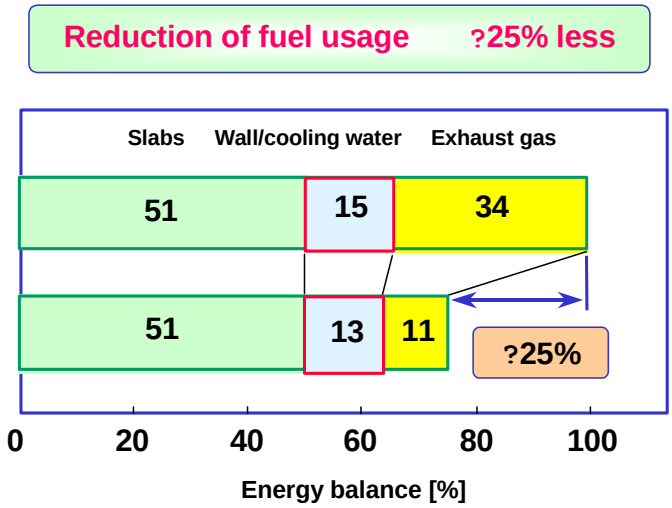
Optimized design
Optimized control



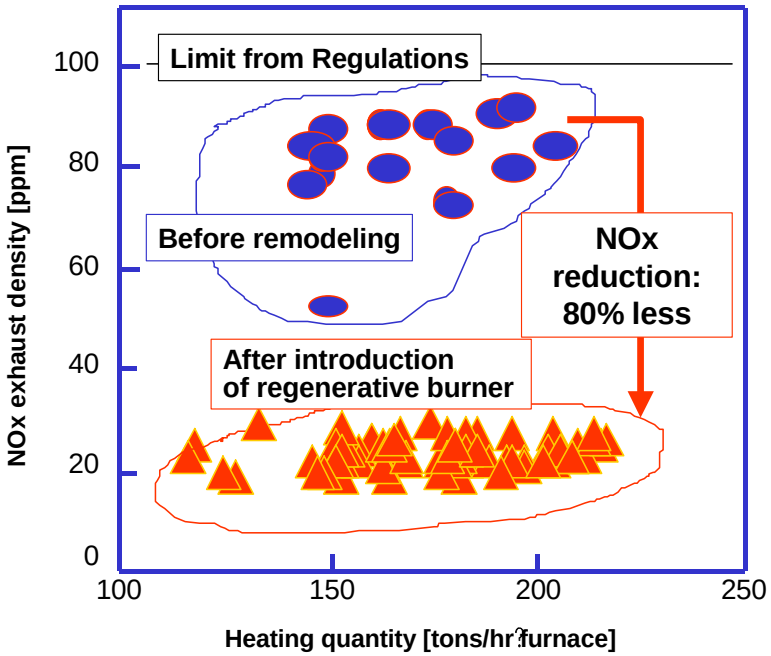
3) Continuous reheating furnace (details)



4)-1 Effect from the introduction of regenerative burners

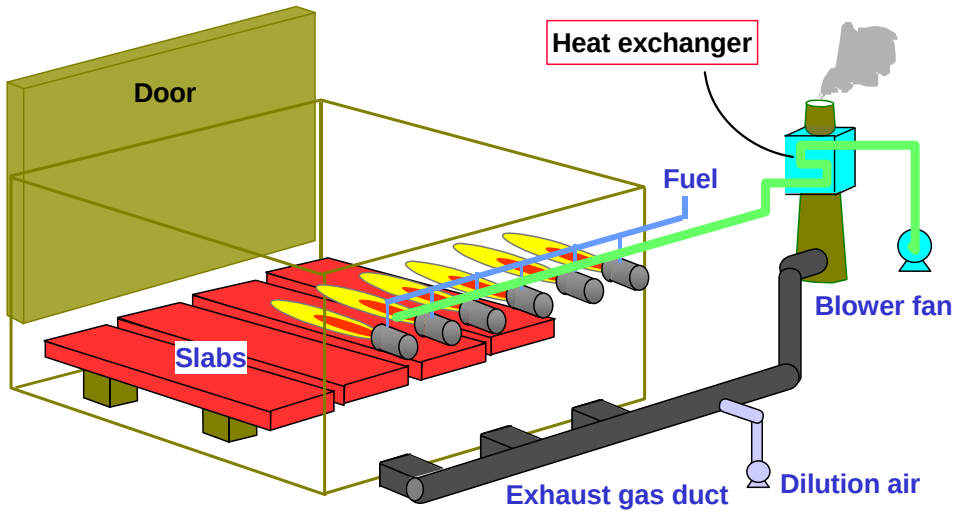


4)-2 Effect from the introduction of regenerative burners

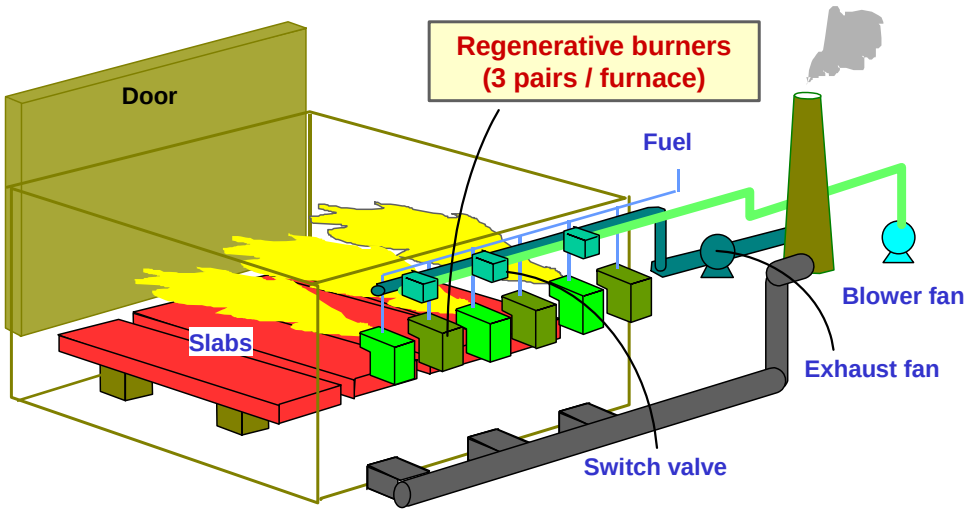


(3) Application example 2: Batch heating furnace

1) Before remodeling

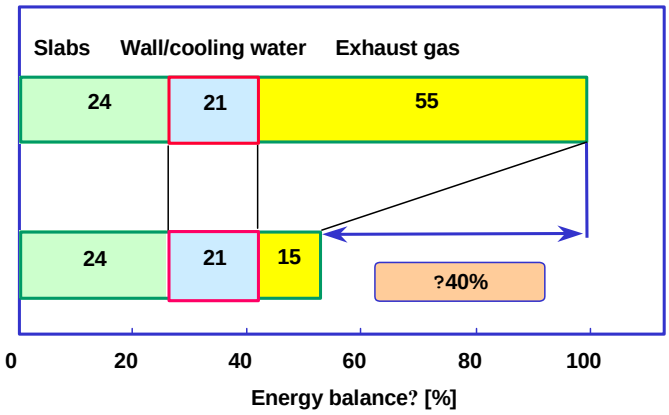


2) After remodeling



3) Effect from the introduction of regenerative burners

Reduction of fuel usage ? 40% less

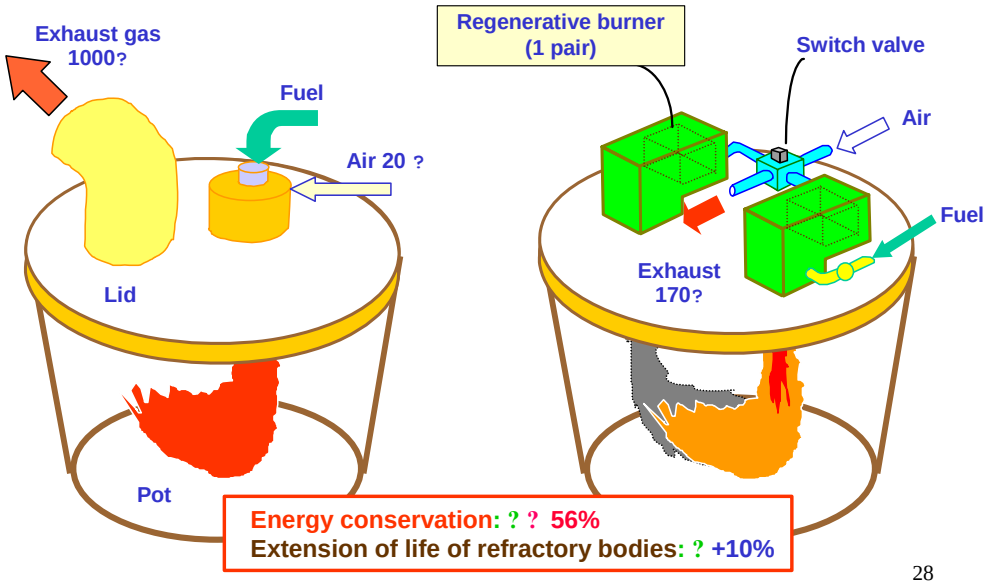


Reduction of NOx emissions ? 60%

(4) Application example 3: Pot heating

Before introduction of regenerative burner

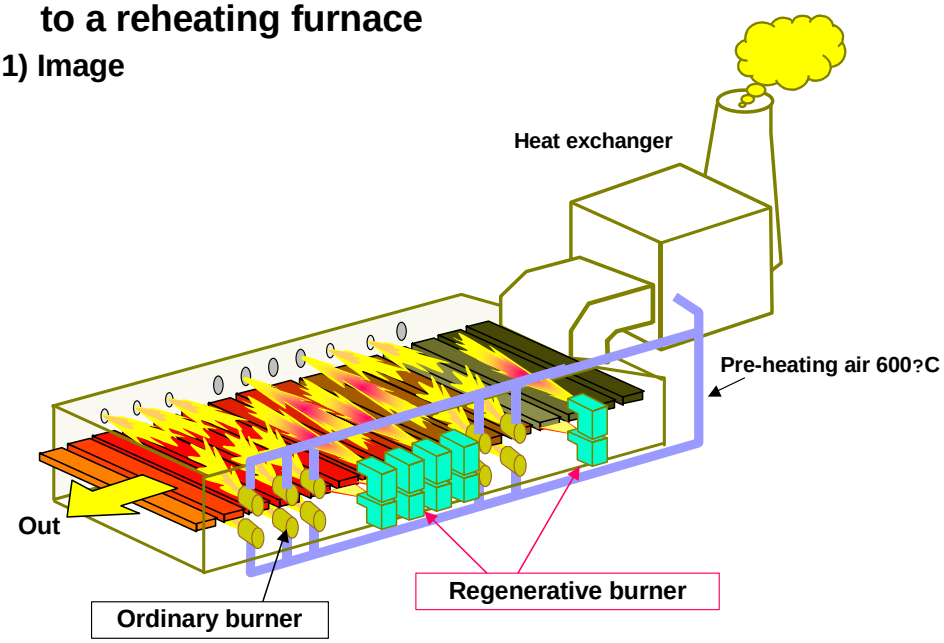
After introduction of regenerative burner



Energy conservation: ? ? 56%
Extension of life of refractory bodies: ? +10%

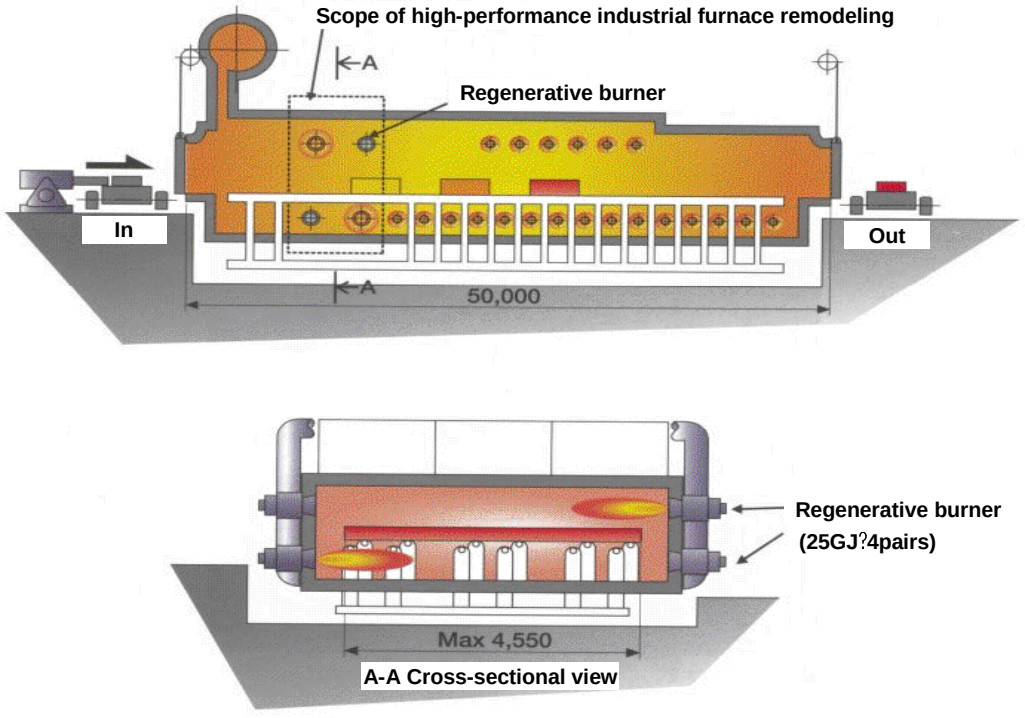
(5) Application example 4: Partial application to a reheating furnace

1) Image



29

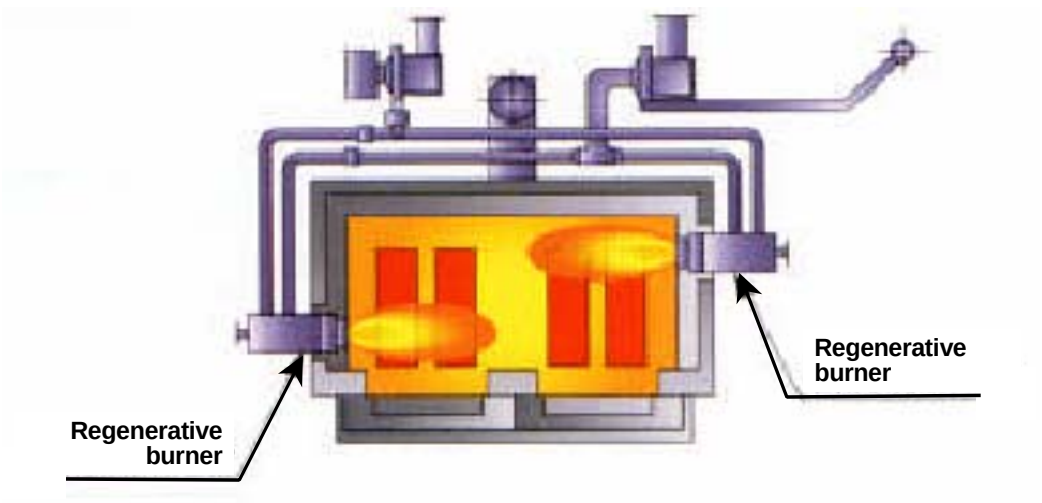
2) Application example



(6) Application example 5: Forging furnace

1) Figure for the application of a regenerative burner

(Source: Japan Industrial Furnace Manufacturers Association)



Fuel source change: A Heavy oil → City gas13A
Energy conservation: 47%

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2) Effect from the introduction of regenerative burners in forging furnaces

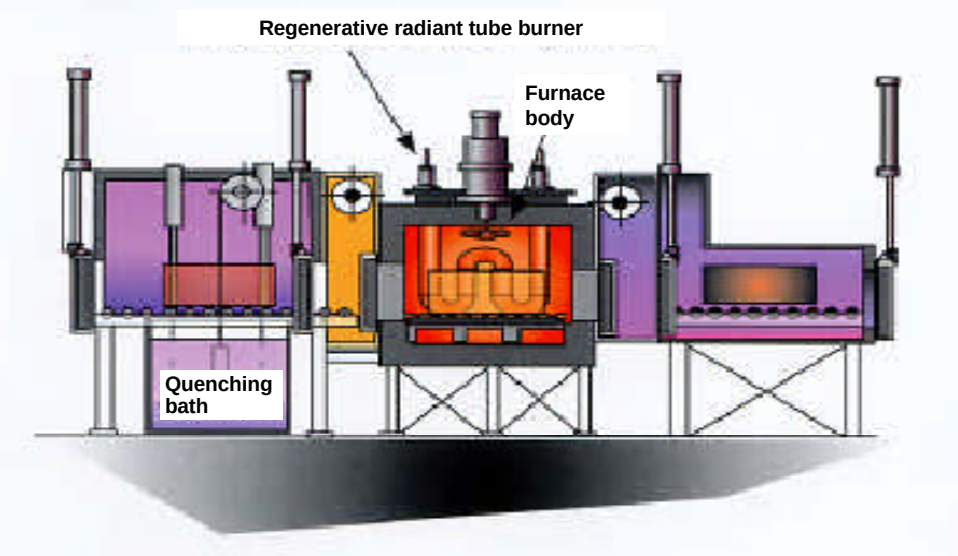
Item		Before remodeling	Furnace with regenerative burner
Conditions	Fuel	A Heavy oil	City gas 13A
	Furnace temperature	1280 C	1280 C
Performance Evaluation	Energy consumption	950,000 kcal/t	500,000 kcal/t (Energy conservation: 47%)
	Temperature distribution inside furnace	Δ t=50 ˚C	Δ t=40 ˚C
	NOx value (Converted into O2=11%)	81 ppm	85 ppm

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(7) Application example 6: Heat treatment furnace

1) Figure for the application of a regenerative burner

(Source: Japan Industrial Furnace Manufacturers Association)



Energy conservation: ? ? 57.7%
NOx emissions: ? 180 ppm→70 ppm

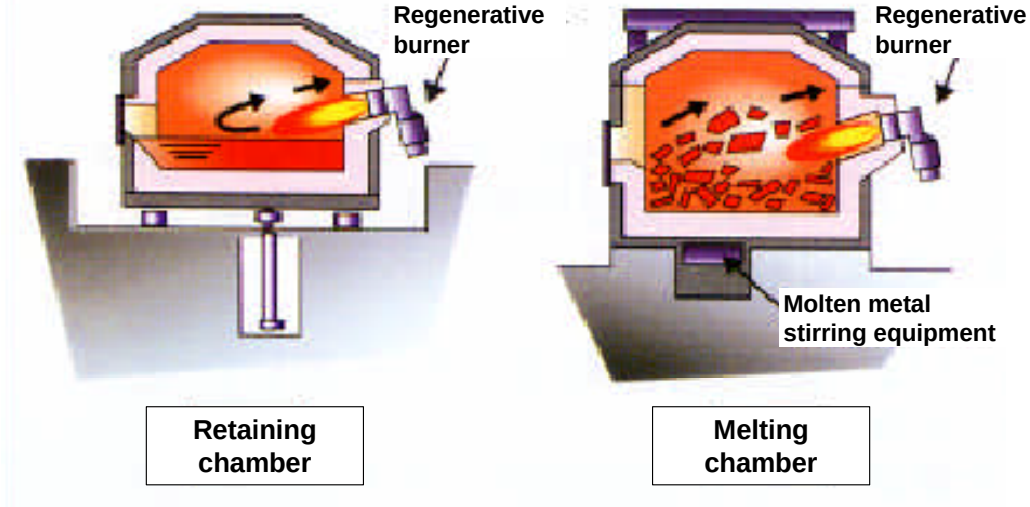
2) Effect from the introduction of regenerative burners in heat treatment furnaces

Item	Conventional furnace	Furnace with regenerative burner
Energy conservation ratio (%):	-	57.7
Heat efficiency (%)	27.5	65.2
Exhaust heat recovery rate (%)	15.1	65.2
NOx value (ppm) (Converted into O_2=11%)	180	70.0

(8) Application example 7: Melting furnace

1) Figure for the application of a regenerative burner

(Source: Japan Industrial Furnace Manufacturers Association)

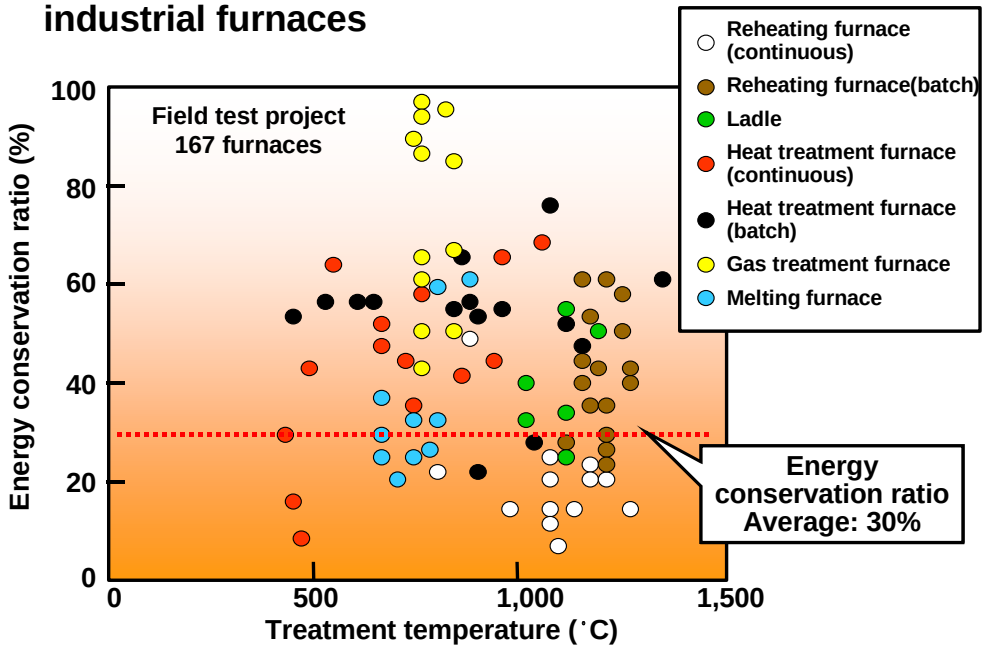


Energy conservation: ? ? 32.2%
NOx emissions: ? 180 ppm → 102 ppm

2) Effect from the introduction of regenerative burners in melting furnaces

Item	Conventional furnace	Furnace with regenerative burner
Energy conservation ratio (%):	-	32.2
Heat efficiency (%)	35.9	52.4
Exhaust heat recovery rate (%)	-	71.7
NOx value (ppm) (Converted into O_2=11%)	180	102

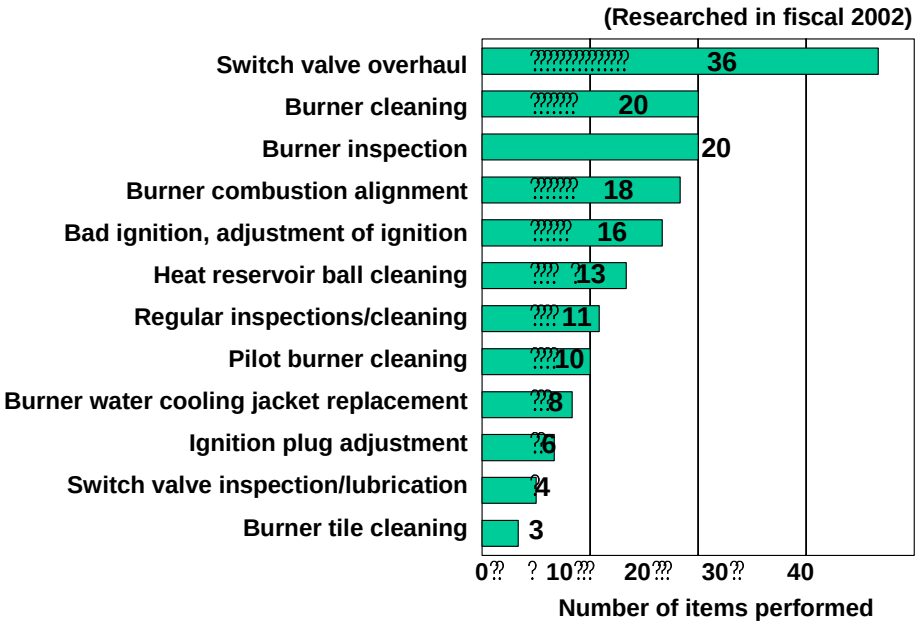
(9) Effect of the introduction of high-performance industrial furnaces



37

(Source: Japan Industrial Furnace Manufacturers Association)

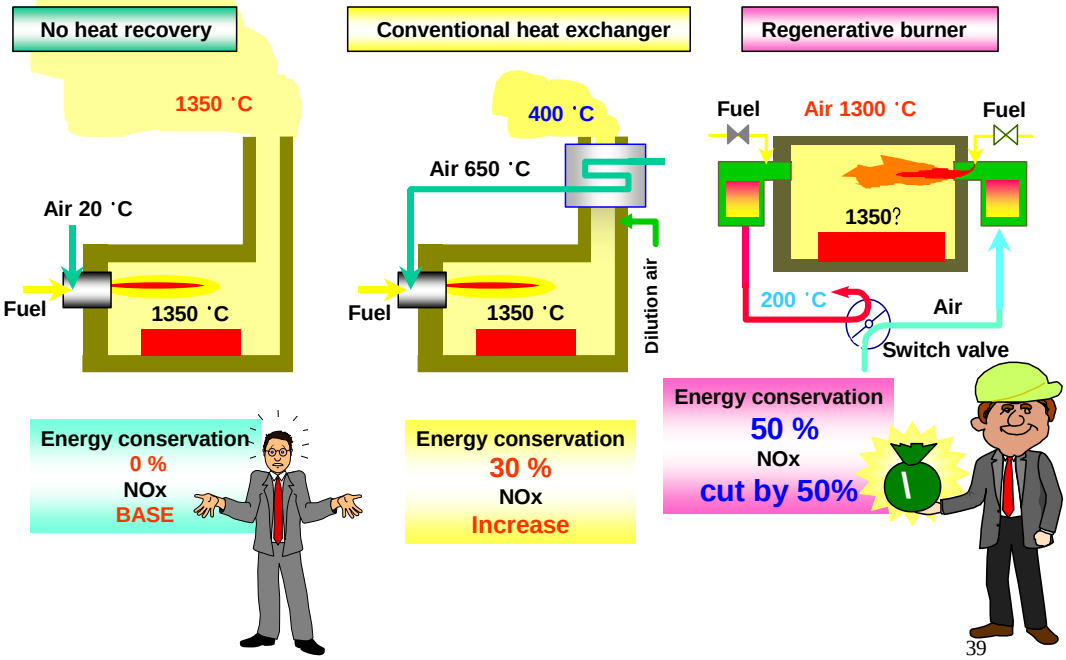
(10) Maintenance of regenerative burners



(Source: Kogyo Kanetsu, Vol. 41, No. 4, p. 19, 2004.7)

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6. Summary


No heat recovery
1350 ˚C
Air 20 ˚C
Fuel
1350 ˚C
Energy conservation
0 %
NOx
BASE
Conventional heat exchanger
400 ˚C
Air 650 ˚C
Fuel
1350 ˚C
Dilution air
Energy conservation
30 %
NOx
Increase
Regenerative burner
Fuel
Air 1300 ˚C
Fuel
1350?
200 ˚C
Air
Switch valve
Energy conservation
50 %
NOx
cut by 50%
39

9. General Energy Savings & Environmental Measures - Background

Environmental Measures in the Japanese Steel Industry

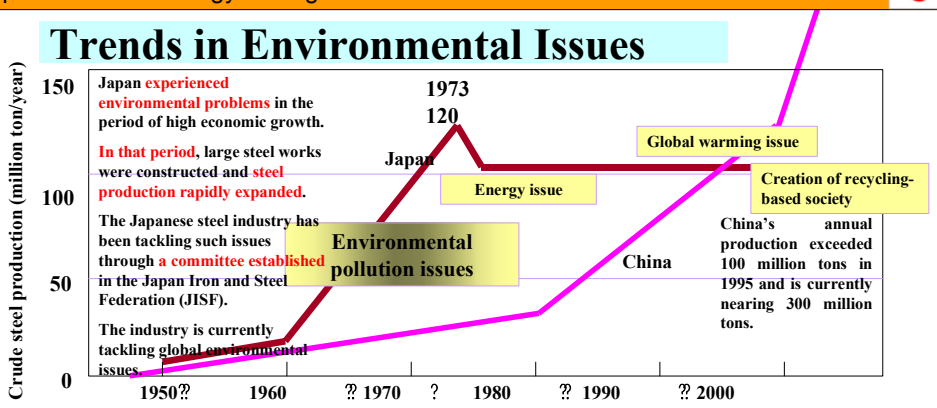
Japan Iron and Steel Federation

Japan - General Energy Savings & Environmental Measures

1. Environmental Issues Surrounding the Japanese Steel Industry
2. Environmental Burden Imposed by Steel Works
   - (1) Environmental Burden Imposed by the Japanese Steel Industry and Management of it
   - (2) Major Environmental Measures for Steel Works
   - (3) Environmental Protection Costs in Steel Industry
3. Environmental Management at Steel Works
   - (1) Mechanism of Japanese Environmental Regulations
   - (2) Agreements between Local Government and Businesses
   - (3) Shift from Legal Regulation to Voluntary Management
   - (4) Environmental Management System
4. Promotion of Technology Development
   - (1) Steel Industry Foundation for the Advancement of Environment Protection Technology (SEPT)
   - (2) Examples of Promotion of Technology Development
   - (3) Life-Cycle Assessment (LCA) of Steel Products
5. Raising Public Awareness and Human Resource Development
   - (1) “Green” Procurement by Customers
   - (2) Communication
   - (3) Education About The Environment
6. Conclusion

1. Environmental Issues Surrounding the Japanese Steel Industry

Trends in Environmental Issues



It is important to eliminate the trade-off between economic growth and environmental issues.

Government efforts	?Establishment of the Environment Agency in 1971 ⟷ Development of environment-related laws and regulations
JISF's efforts to tackle environmental issues	?Establishment of the Factory Location and Environmental Pollution Committee in 1967 ?Formulation of the Voluntary Action Program of JISF in December 1996 ?Establishment of the JISF Headquarters for the Development of NOx Control Technology in Steel Industry and the JISF Slag Recycling Committee in 1973

2. Environmental Burden Imposed by Steel Works

(1) Environmental Burden Imposed by the Japanese Steel Industry and Management of it

Unit: 1,000 t/year (FY2002)

Energy sources, etc.
Fuel, electricity
Water for industrial use

Raw material
Iron ore 121,000
Coking coal 63,800
Lime, fluorite

Chemicals
Coating, resin
Galvanization agent, etc.

PRTR chemicals 7.28

CO2 emission 181,000

Use of by-product gases
Use of circulating water
Recycling of energy

Japanese steel industry
Pig iron 81,500
Crude iron 109,800
By-products 45,200

Exhaust gas
Drainage
Dust, noise, vibration
Emission control

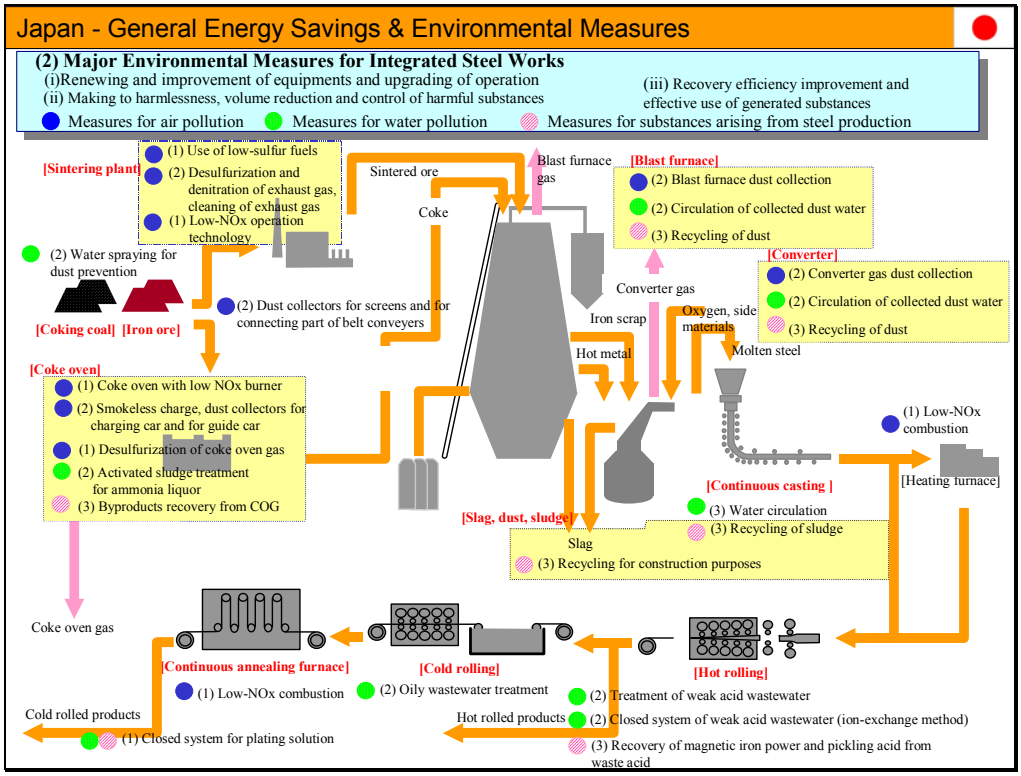
Use of by-products from other industries

Recycling of steel industry by-products

Recycling of resources 98%

Final disposal 720

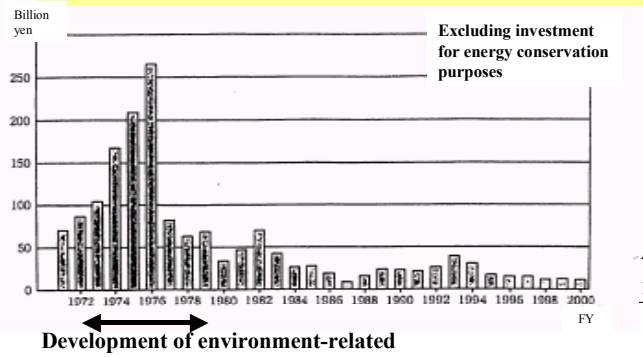
Japan - General Energy Savings & Environmental Measures

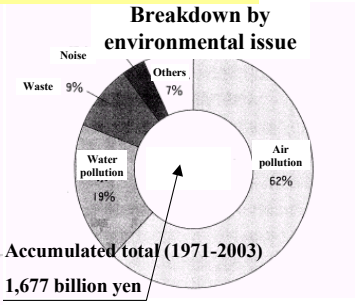


Japan - General Energy Savings & Environmental Measures

(3) Environmental Protection Costs in Steel Industry

(i) Environmental Equipment Investment in the Japanese Steel Industry





Investment in environmental equipment (in the narrow sense) accounted for 7.2 % of total cumulative equipment investment.

Currently, with countermeasures in place, it accounts for about 4% to 5 % each year.

Example of Environmental Protection Costs (Expenses)

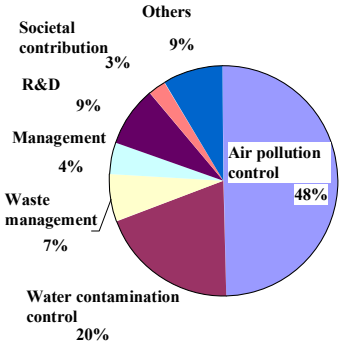
•At the company given as an example, air pollution-related costs account for about 50% of the total environmental protection costs. This trend is also seen at other companies.

•Most air pollution-related costs arise from the electric power cost for dust collectors. In order to implement both environmental measures and energy conservation measures, the environmental technology for efficient gas absorption is critical.

Environmental protection costs 1,600 yen/t-s

Category	Contents
Environmental measures	Air pollution control
	Water contamination control
Waste management	Landfill and contract disposal of industrial waste
Management	Monitoring and measurement of environmental burden Personnel costs for organizations in charge of environmental measures
R&D	Development of eco-products Development of technology to reduce environmental burden in the manufacturing process
Societal contribution	Afforestation, support for environmental organizations
Others	SOx charges

Percentage by category



Japan - General Energy Savings & Environmental Measures

3. Environmental Management at Steel Works

(1) Mechanism of Japanese Environmental Regulations

Environmental quality standards:
Target values (not directly regulating emissions)
Air, soil: Nationwide uniform targets
Water (hazardous substances): Nationwide uniform targets
Water (COD, etc.): Targets set by water area depending on water use

Central Environmental Council

National government (laws): Set national minimum emission standards

Local government (ordinances): Set more stringent emission standards than national standards or independent standards for items not regulated by the national government

Regulating emissions from places of businesses in specified control areas: Total pollutant load control

Businesses and business associations

Implementing voluntary management

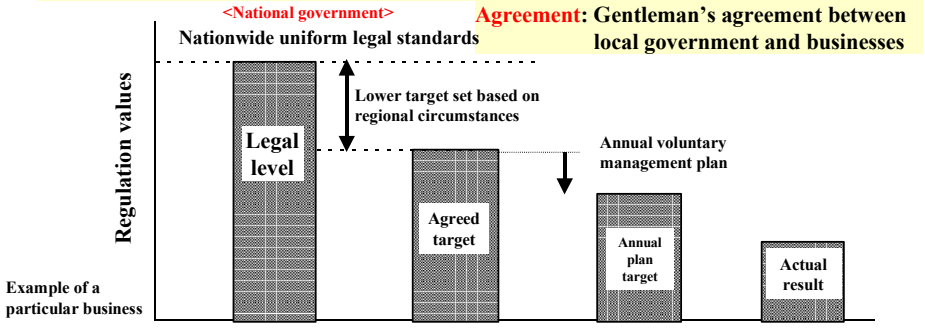
Measures for facilities in compliance with the regulatory standards and operation management

*** Countermeasure implementation method left up to the individual company.**

Japan - General Energy Savings & Environmental Measures

(2) Agreements between Local Government and Businesses

Businesses conclude agreements with local government on more stringent regulation targets than statutory regulations.



Total pollutant load control	Legal level (maximum)	Agreement		Actual result (average)
		Agreed level (maximum)	Annual plan target (maximum)	
SOx Nm^3/h	405	405	106	25
NOx Nm^3/h	□	395	246	110
COD kg/d	2,563	1,245	1,245	705
Suspended solids kg/d	□	1,115	1,115	166

(3) Shift from Legal Regulation to Voluntary Management by Businesses

- Diffusion of the ISO 14000 Environmental Management System
- Amendment of the Air Pollution Control Law to include measures to reduce hazardous air pollutants (e.g. benzene) in 1996
  - Voluntary management approach
  - Reduction targets set by the industry (target fiscal year: FY1999)
- Evaluation of the implementation status in 2000?

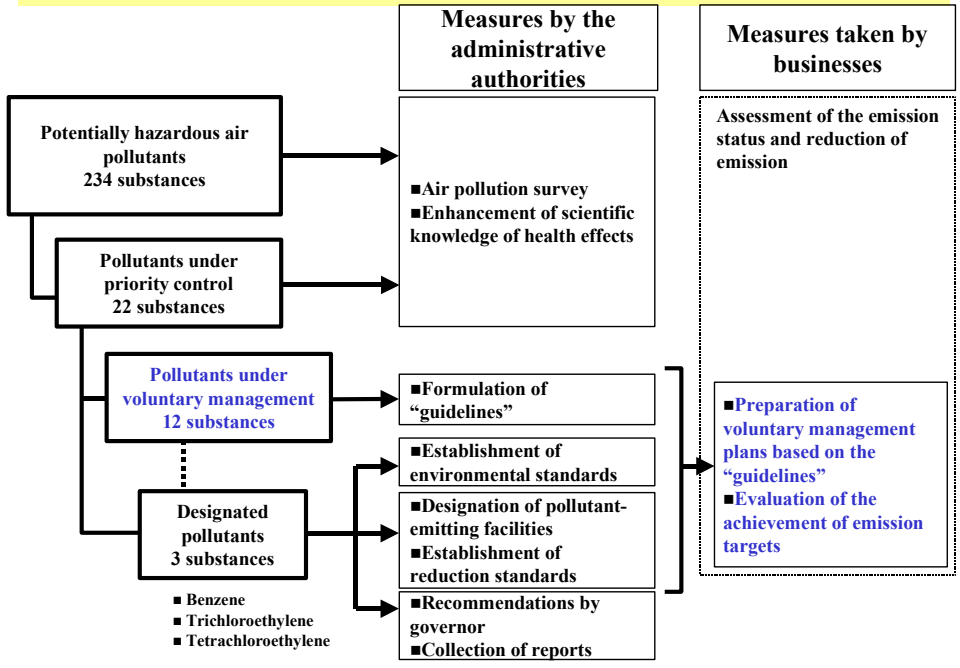
Environmental improvement effect

Economic efficiency

Administrative expenses

The voluntary management approach is evaluated as effective for emission reduction

System for Measures against Hazardous Air Pollutants



First Voluntary Management Plan (1)

Efforts in Steel Industry

Benzene:

(Unit: t; %)

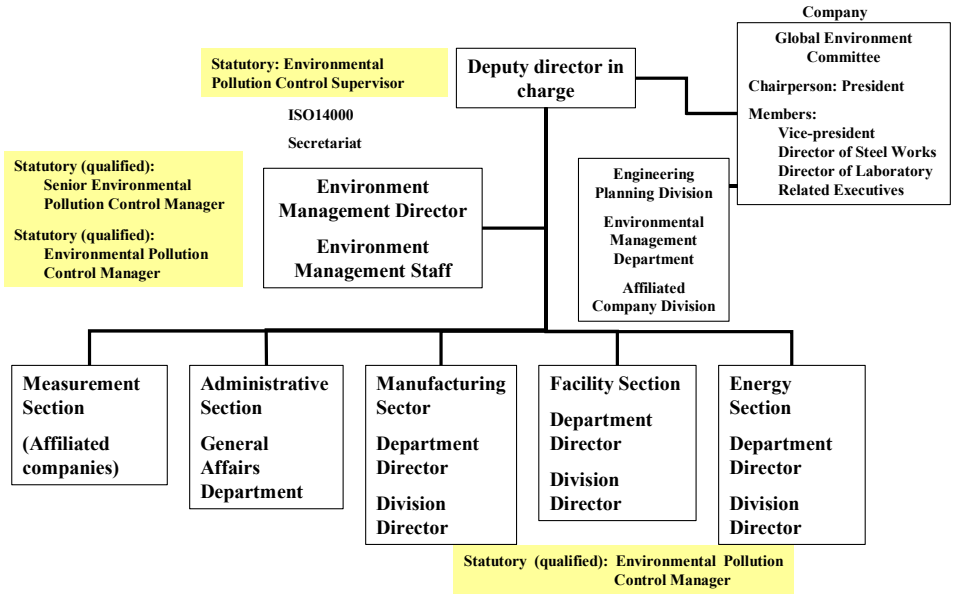
	FY1995 level (Basis)	FY1999		Achievement rate	Reduction rate
		Target	Actual result		
Emission (Changing cars)	57	40	36	124%	37%
Leakage from door	15	10	2.5	250%	83%

Trichloroethylene, tetrachloroethylene, dichloromethane

(Unit: t; %)

	FY1995 level (Basis)	FY1999		FY2000	Achievement rate	Reduction rate
		Target	Actual result	Actual result		
Trichloroethylene	550	387	391	345	126%	37%
Tetrachloroethylene	62	43	51	39	121%	37%
Dichloromethane	1,158	913	1,394	910	101%	21%

Environmental Management System at Steel Works



4. Promotion of Technology Development

(1) Steel Industry Foundation for the Advancement of Environment Protection Technology (SEPT)

Since its establishment as a NOx fund in 1973, the SEPT has provided subsidies for research on steel-related environmental protection technology for more than 30 years.

Objectives
(1) Development of steel-related environmental protection technology
(2) Development of technology for effective use of substances arising from steel production
(3) Enhancement of scientific knowledge of environmental impact of steel industry
(4) Development of effective technology for international cooperation

SEPT

Invite research subjects
Apply
Grant subsidies
Report on research results

Researchers at universities and institutes

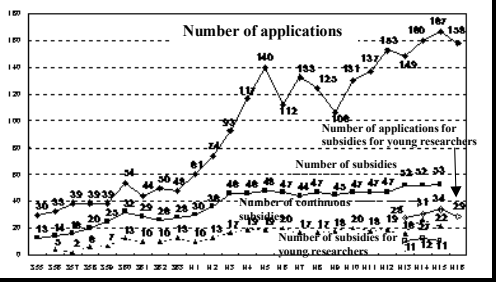
Contributions from businesses

JISF members

Research issues for technology development relating to steel

JISF Engineering Environment Committee

Promotion of research on efficient environmental technology



Environmental Research Projects in Steel Industry

	1994	1996	1998	2000	2002	2004
Air/water pollution				Technology for suspended particulate matter →		
		Technology for benzene and dioxin →				
					Impact of zinc on ecosystem →	
			Technology for fluoride effluent treatment →			
Substances arising from steel production	Treatment and effective use of slag, dust, and sludge →					
				Turning slag into a high value added product →		
				Treatment of waste other than that from steel →		
Global environment					Steel manufacturing technology for drastic CO2 reduction →	
					CO2 sequestration technology →	

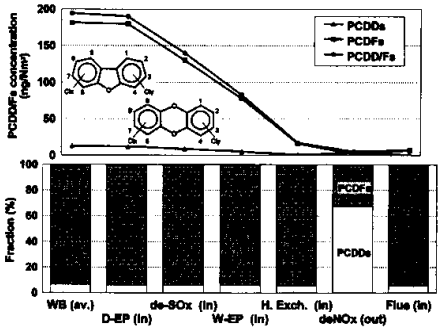
(2) Examples of Promotion of Technology Development

(i) Research on reduction of dioxin generated form a sintering plant

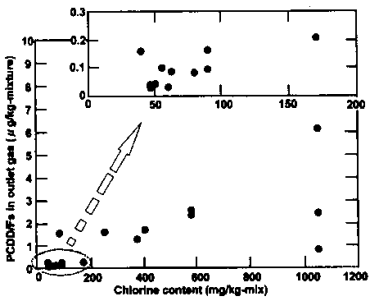
Large scale research subsidies granted from 1997 to 2000

Industry-academia joint research (four university researchers and seven blast furnace steel manufacturers participated)

Research was conducted on the mechanism for dioxin emission and reduction technology.



Changes in the PCDD/F concentration in the process of exhaust gas treatment



CI concentration in raw materials and generation of PCDD/F

(2) Technology for Effective Use of Slag

- Characteristics of concrete made form electric furnace slag and low-quality aggregate
- Development of technology for restoring ecosystem in water areas using converter slag as a purification catalyst
- Research on the mechanism for preventing dusting of smelting slag
- Development of technology for using blast-furnace slag as material for land improvement
- Detoxification and effective use of tramp elements arising from iron scrap

(3) Life-Cycle Assessment (LCA) of Steel Products

•JFE Steel established LCA technology through collaboration with the International Iron and Steel Institute (IISI).

•As a member of the LCA Japan Forum, JFE Steel provides data on the environmental burden posed by steel for customers and researchers.

Steel products	Stainless steel products
Hot rolled plate and sheet Cold rolled plate and sheet Tin-free plate and sheet Tin plate and sheet Electrogalvanized plate and sheet Hot dip galvanized plate and sheet Thick plate Welded tube Special steel products Molded steel Bar steel Cast iron	Hot rolled stainless steel plate and sheet (heat treatment, acid pickling) Ni-type Hot rolled stainless steel plate and sheet (heat treatment, acid pickling) Cr-type Cold rolled stainless steel plate and sheet (heat treatment, acid pickling) Ni-type Cold rolled stainless steel plate and sheet (heat treatment, acid pickling) Cr-type Cold rolled stainless steel plate and sheet (bright annealing) Ni-type Cold rolled stainless steel plate and sheet (bright annealing) Cr-type Stainless bar steel Ni-type
Total: 12 items	Total: 7 items

Environmental burden data provided
•Air: CO2 and 9 other items
•Water: BOD, COD
•Waste: Amount of solid waste discharged

Customers: LCA of automobiles and electric appliances, evaluation of environmental performance of products
Indication of data with "Eco Leaf" label.
Steel industry: Development of environmentally-friendly steel products

5. Raising Public Awareness and Human Resource Development

(1) "Green" Procurement by Customers

- Choosing materials based on the reduction in environmental burden
- Avoiding use of materials containing hazardous substances
  - Providing chromate-free plate and sheet
  - Avoiding use of cadmium, lead, etc.
- Satisfying demand for environmental information
  - Providing Material Safety Data Sheet (MSDS)
  - Providing LCA data

Trends in Regulations for Substances of Concern

	2003	2004	2005	2006	2007
Japan			?Prohibition of substances of concern (JAMA accord) Mercury (end of 2004)		90% reduction in lead (2006) Cadmium (2007) Hexavalent chromium (2008)
	?Amendment of the Law Concerning Examination and Regulation of Manufacture and Handling of Chemical Substances in 2003				
EU	?Prohibition of substances of concern in end-of-life vehicles (ELV) in 2003 Lead, mercury, cadmium, hexavalent chromium			?Prohibition of substances of concern in electrical and electronic equipment in 2006-2007 Lead, mercury, cadmium, hexavalent chromium	
				?China (RoHS) Regulation in 2006-2007	
		?EU Chemical Directives (on Registration, Evaluation, Authorization of Chemicals) adopted in 2003 Hazardous chemicals in general			?Regulations to be established at the end of 2006?

(2) Communication

- Publication of environmental reports by steel companies
- JISF efforts to raise public awareness
  - Declaration of its views on “countermeasures against global warming”
  - Publication of the pamphlet entitled “Global Warming A to Z”
  - Participation in the Eco-Life Fair to show its commitment to environmental issues



(3) Education About The Environment

- Personnel education (human resource development) at a company

		Education under the personnel system **"Environmental energy course"** **Mid-career employees before promotion to the management level**	**Technical employees** **Obligation to obtain a statutory environment-related qualification** **(e.g. Environmental Pollution Control Manager)**
Group I	**Upon joining the company** **Education for fresh recruits** **Environment Department**	**Providing education for employees to make them aware of environmental management issues** **Providing training on responses in environment-related emergencies**	
Group II	**Upon joining the company** **Education for fresh recruits** **Environment Department**		

Japan - General Energy Savings & Environmental Measures

6. Conclusion

Experiences of the Japanese Steel Industry

Effective environmental measures taken by the Japanese steel industry

(i) Disclosure of information on environmental problems by all companies

(ii) Information sharing and technical discussion via the JISF

(iii) Joint environmental technology development by the industry as a whole

Approach to Energy Saving of Japanese Steel Industry

The Voluntary Action Program of JISF

Japan Iron and Steel Federation

Japan – General Energy Savings & Environmental Measures

1. About the Voluntary Action Plan of JISF

1. The Voluntary Action Program of JISF against Global Warming
2. Examples of Major Energy Saving Equipment at Integrated Steelworks
3. Transition of Energy Consumption in the Japanese Steel Industry
4. Energy Saving Efforts and Evaluation
5. Adoption Ratio of Major Energy Saving Equipment
6. Examples of Major Energy Saving Equipment at Integrated Steelworks
7. Investment for Energy Saving and Environmental Protection by Japanese Steel Industry
8. Comparison of Specific Energy Consumption among Major Steel Making Nations
9. Waste Plastic Recycle
10. Contribution of Steel Products to Energy Savings in Society
11. Contributions to Energy Savings in Society with by-products
12. Contribution of International Technical Cooperation to Energy Saving
13. Use of Unused Energy in the Vicinity Region
14. Overview of Achievement in Voluntary Action Plan of the Japanese Steel Industry

2. About a Mid/long-term, Technological Development

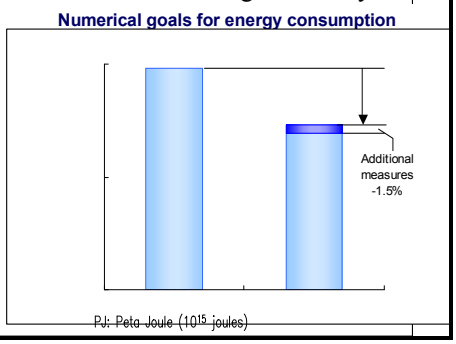
1. Development of a New Sintering Process for Reducing CO2 Emissions
2. Development of Highly Effective Hydrogen Processing Technology
3. CO2 Sequestration Process by Carbonation of Steel Making Slag
4. Eco-complex

Conclusion

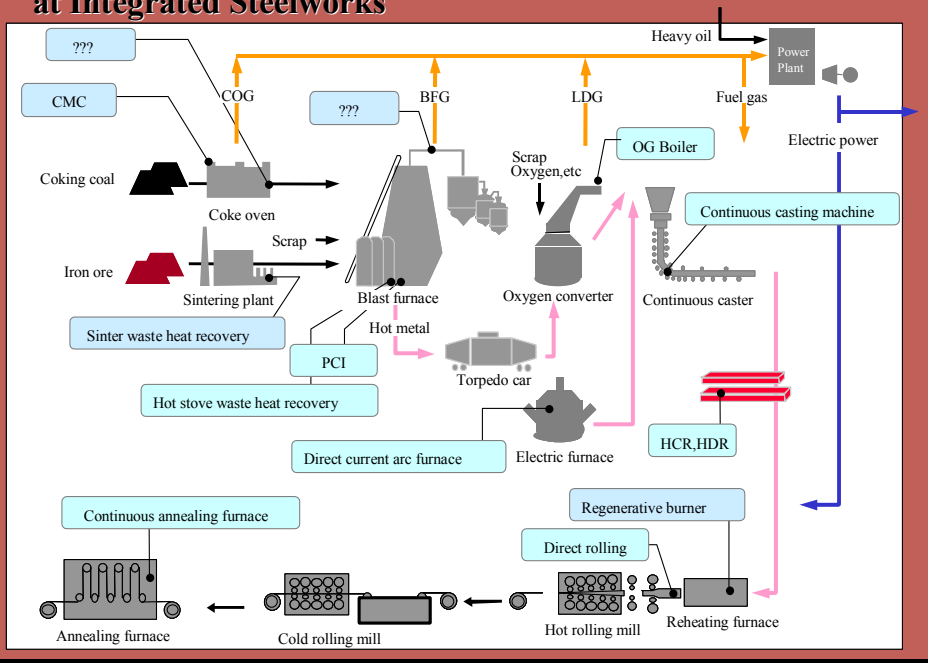
Japan – General Energy Savings & Environmental Measures

1. The Voluntary Action Program of JISF against Global Warming Established in December 1996

1. Efforts to save energy in iron and steel making process.
•10% reduction in energy consumption as its goal for the year 2010 compared to 1990 levels (on the assumption of the crude steel annual production of 100 million-ton level).
2. Effective utilization of plastic and other waste materials Additional measures?
•1.5 reduction under the condition of establishing classification and collecting scheme by local government.
3. Contributions to energy saving in society with steel products and by-products.
4. Contributions to energy saving through international technical cooperation.
5. Utilization in areas around steelworks of energy unused in iron and steel making.

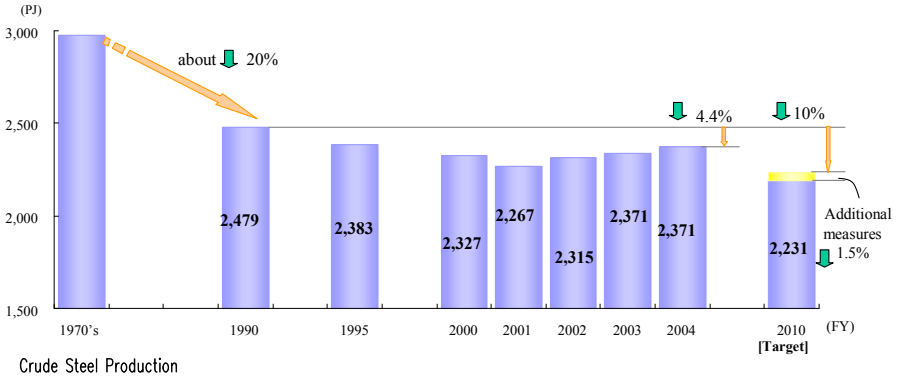


2. Examples of Major Energy Saving Equipment at Integrated Steelworks



Japan – General Energy Savings & Environmental Measures

3. Transition of Energy Consumption in the Japanese Steel Industry

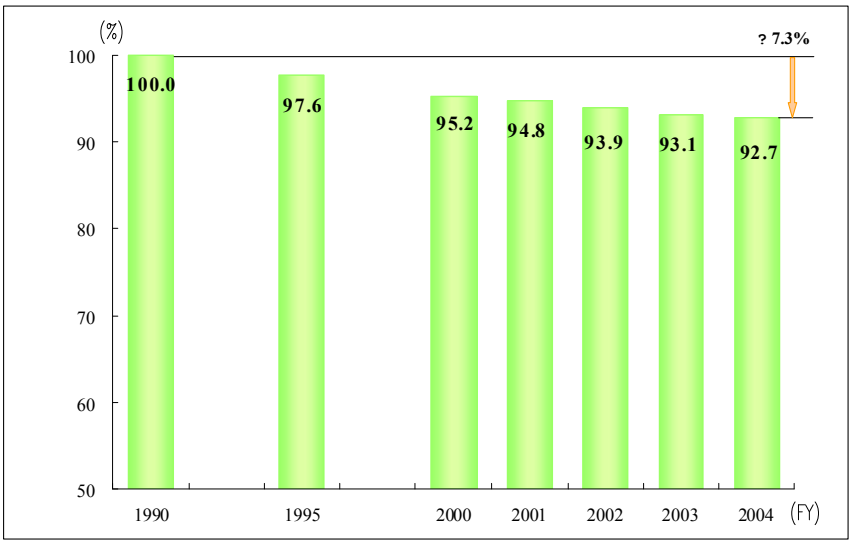


Crude Steel Production

Crude Steel Production (Million tons)	112	100	107	113

Transition of Energy Unit Requirement*

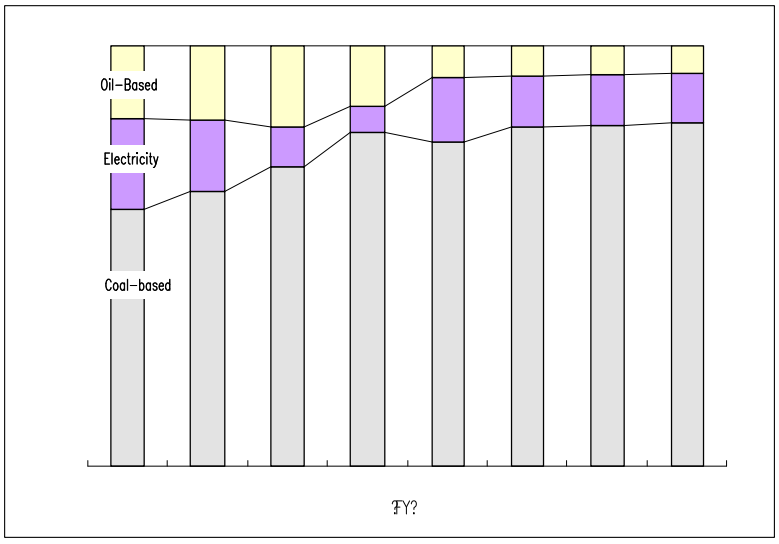
(The year 1990 = 100%)



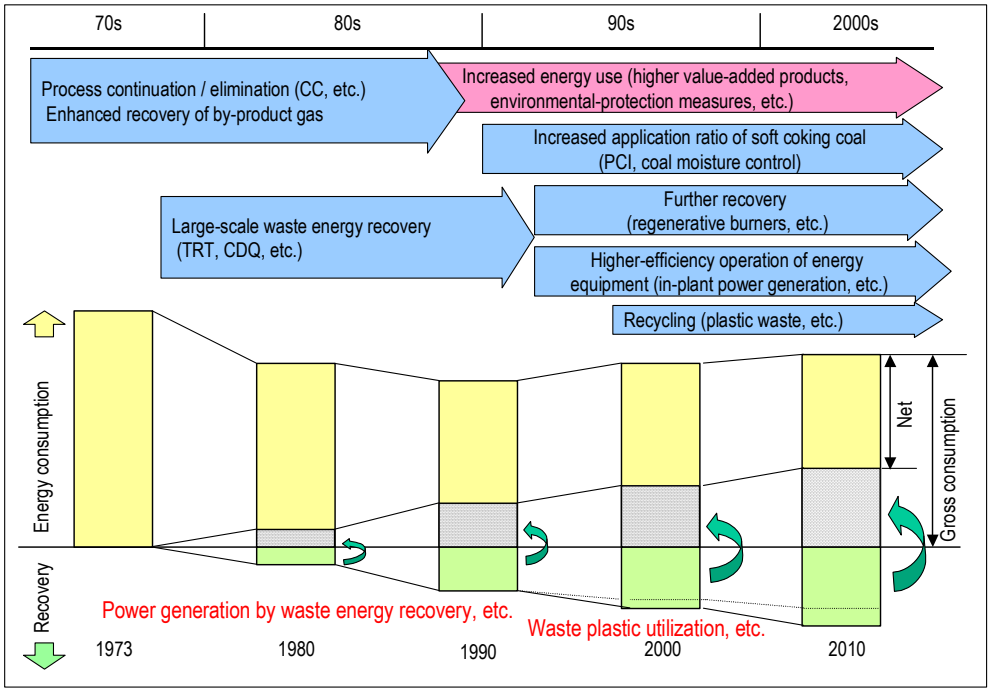
*Energy unit requirement is energy consumption for ton of crude steel, modified based on production situation in 1990.

Feature of Energy Consumption of Japanese Steel Industry

Transition of Energy Source of Japanese Steel Industry

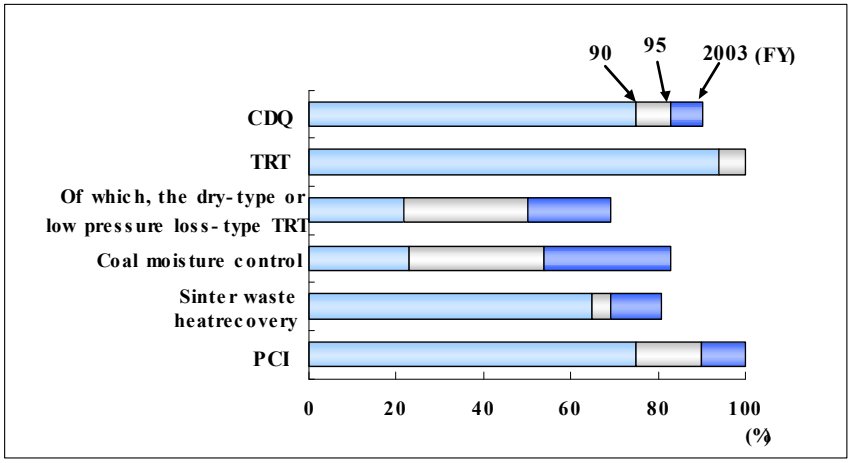


4. Energy Saving Efforts and Evaluation

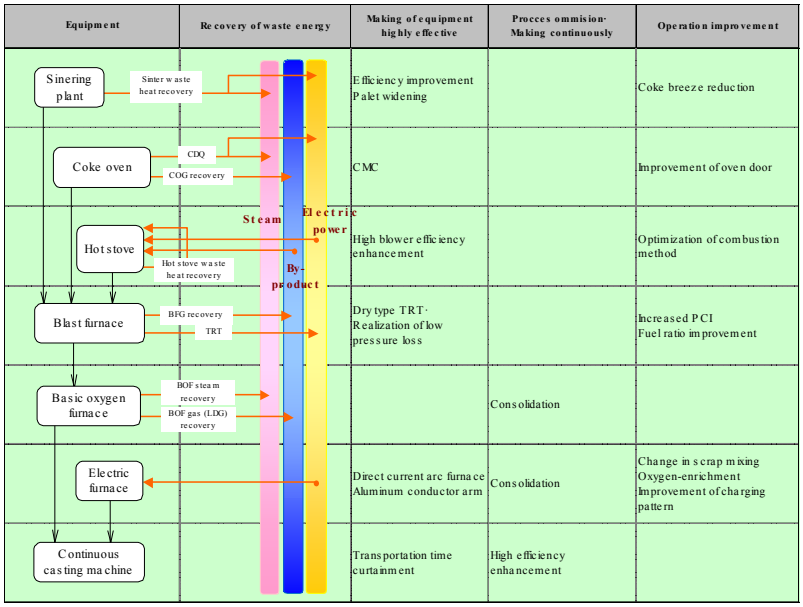


Japan – General Energy Savings & Environmental Measures

5. Adoption Ratio of Major Energy Saving Equipment

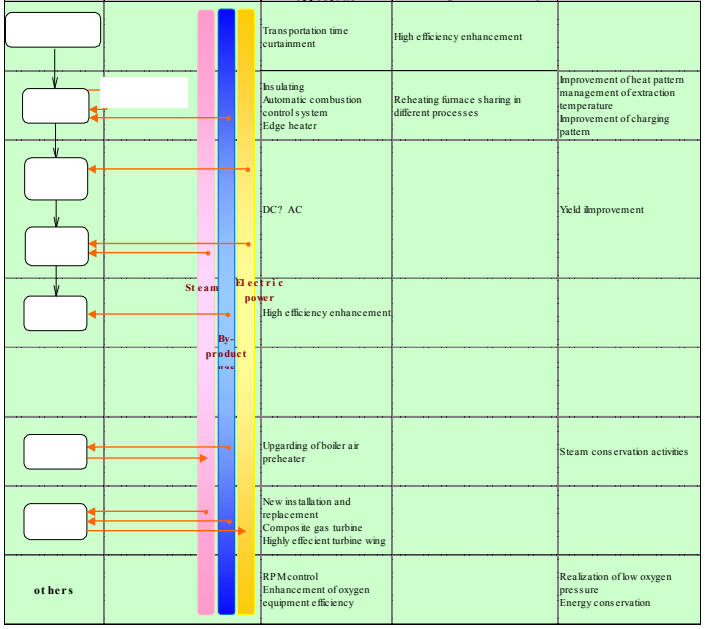


6. Examples of Major Energy Saving Equipment at Integrated Steelworks (1)



Equipment	Recovery of waste energy	Making of equipment highly effective	Process ommision· Making continuously	Operation improvement
Sinering plant	Sinter waste heat recovery	Efficiency improvement Palet widening		Coke breeze reduction
Coke oven	CDQ COG recovery	CMC		Improvement of oven door
Hot stove	Hot stove waste heat recovery	High blower efficiency enhancement		Optimization of combustion method
Blast furnace	BFG recovery TRT	Dry type TRT· Realization of low pressure loss		Increased PCI Fuel ratio improvement
Basic oxygen furnace	BOF steam recovery BOF gas (LDG) recovery		Consolidation	
Electric furnace		Direct current arc furnace Aluminum conductor arm	Consolidation	Change in scrap mixing Oxygen-enrichment Improvement of charging pattern
Continuous casting machine		Transportation time curtainment	High efficiency enhancement	

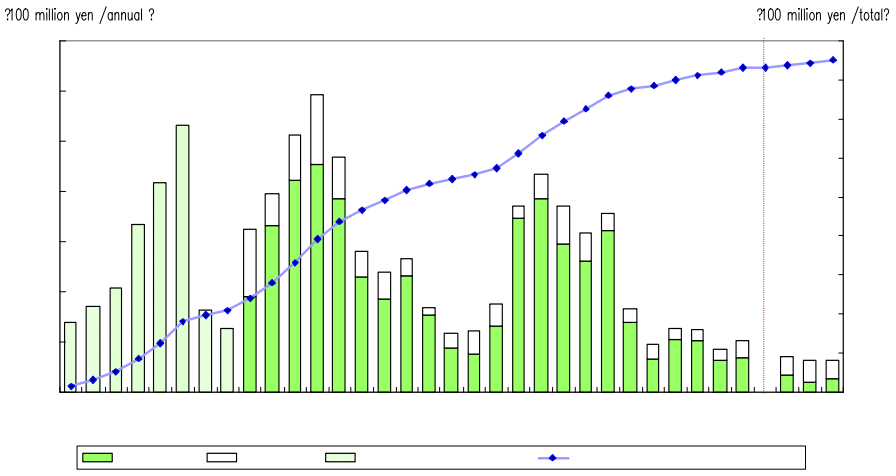
Examples of Major Energy Saving Equipment at Integrated Steelworks (2)



Equipment	Waste energy recovery	Making of equipment highly	Process omission ·Making continuously	Operation improvement
		Transportation time curtainment	High efficiency enhancement	
		Insulating Automatic combustion control system Edge heater	Reheating furnace sharing in different processes	Improvement of heat pattern management of extraction temperature Improvement of charging pattern
		DC? AC		Yield improvement
		High efficiency enhancement		
		Upgarding of boiler air preheater		Steam conservation activities
		New installation and replacement Composite gas turbine Highly effecient turbine wing		
others		RPM control Enhancement of oxygen equipment efficiency		Realization of low oxygen pressure Energy conservation

7. Investment for Energy Saving and Environmental Protection by Japanese Steel Industry

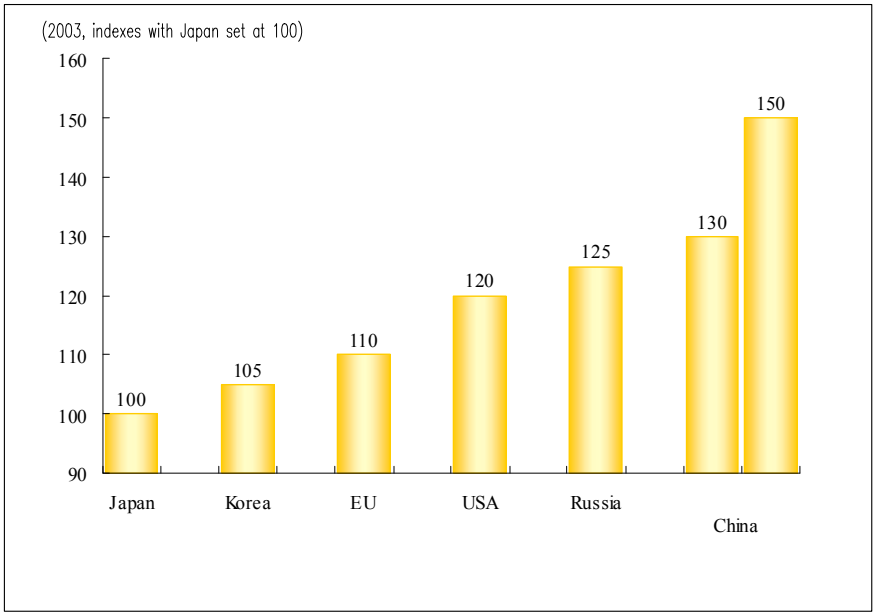
The total of investment:3trillion yen('71-'89),1.5t yen('90-'04)



Note:Statistics in the 2004 fiscal year are plan and before 2004 are actual.
Energy-saving investment investigation started from the 1979 fiscal year.

Source:METI

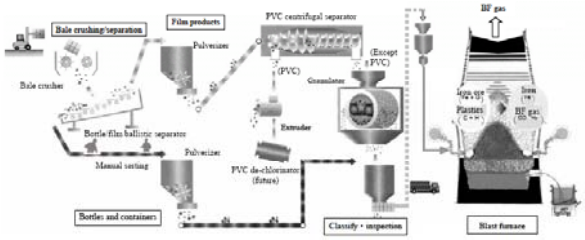
8. Comparison of Specific Energy Consumption among Major Steel Making Nations



9. Waste Plastic Recycle

Applied Process for Waste Plastic

Blast Furnace

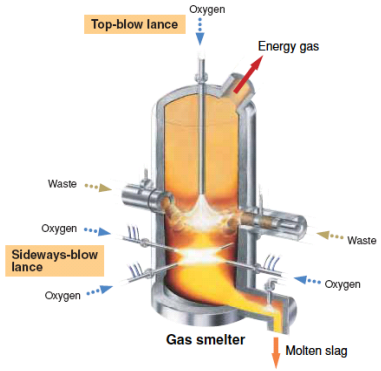


Coke Oven



Used as a reduction material.

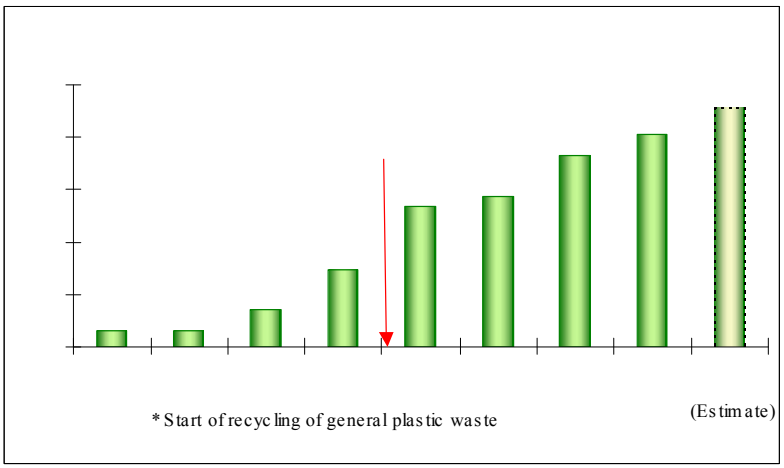
Gasification Smelting Furnace



Used as a energy gas.

Japan – General Energy Savings & Environmental Measures

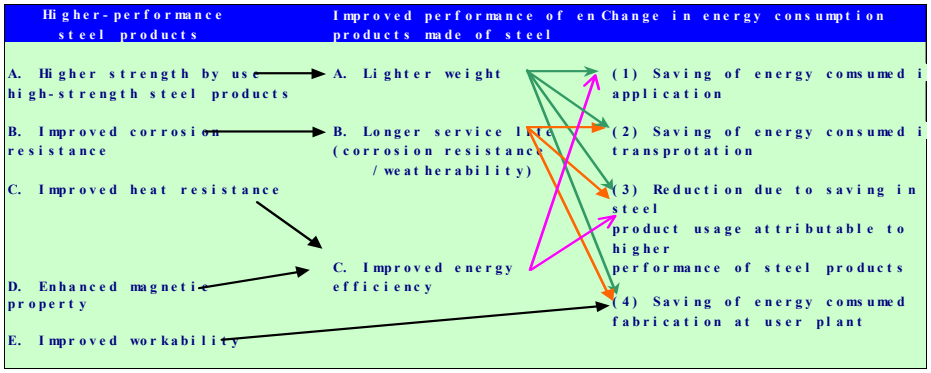
(2) Recycling of Waste Plastic and Used Tire in Blast Furnaces and Other Equipment



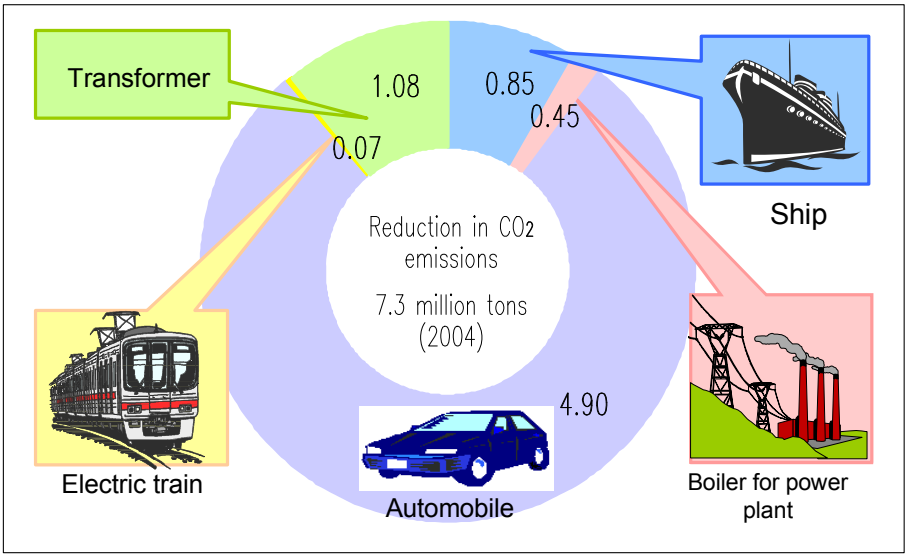
10. Contribution of Steel Products to Energy Savings in Society

(Outside of Steel Works)

(1) Concept of Effects on Energy Saving Offered by Using end Products? Manufactured with Higher-performance Steel Products



(2) Estimation of Cumulative Reduction in CO2 Emissions Attained by Five Higher-performance Steel Products* Manufactured from 1990 to 2004 (Snapshot in 2004)

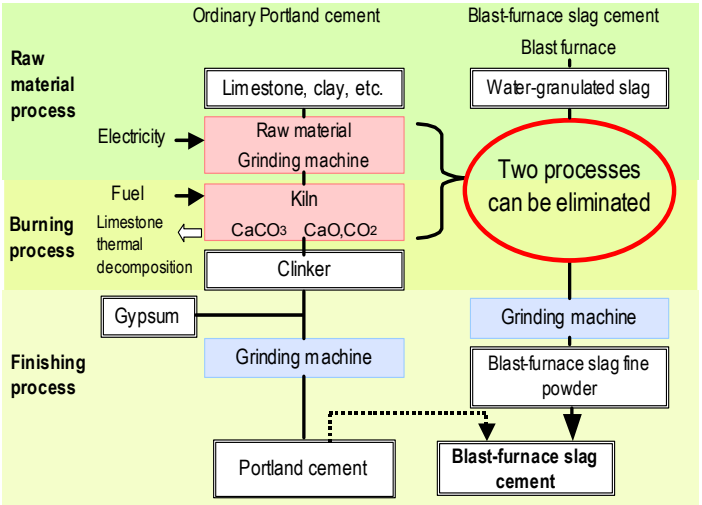


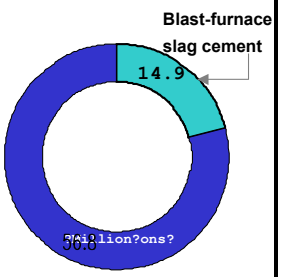
*Five products: Automotive high-strength steel sheets, high-strength shipbuilding plates,high-strength stainless steel sheets, grain-oriented electrical steel sheets for transformers, heat-resistant steel tubes for boilers

11. Contributions to Energy Savings in Society with by-products

(Outside of Steel Works)

Blast furnace slag cement reducing fuel consumption by 43% and CO_2 emissions by 41%.





Amount of CO2 reduction

46.5 Mt

12. Contribution of International Technical Cooperation to Energy Saving

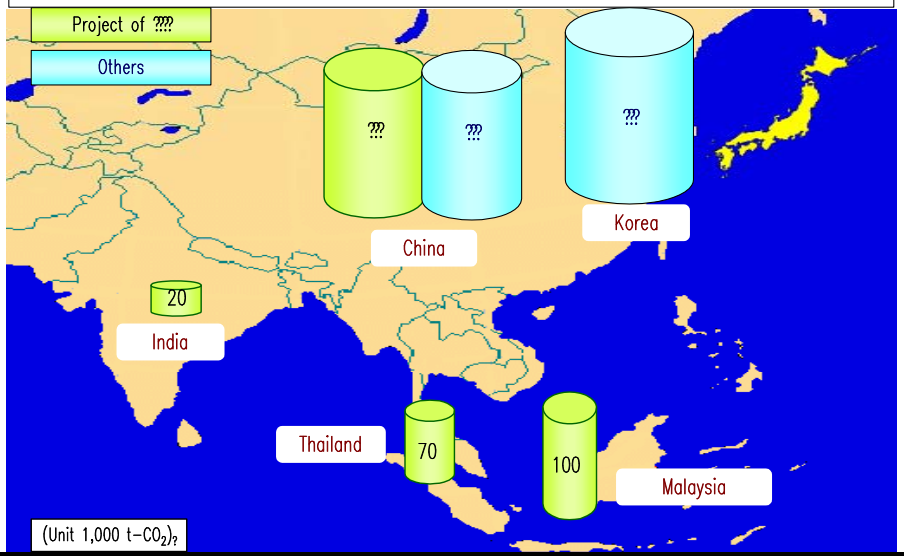
(Outside of Steel Works)

(1) CO_2 Emission Reduction by International Technical Cooperation

✧ The effect of the CO2 emission reduction of the Model Project for the Efficient Use of Energy of NEDO(13) that had been executed by 2003 is about 500,000t-CO2.

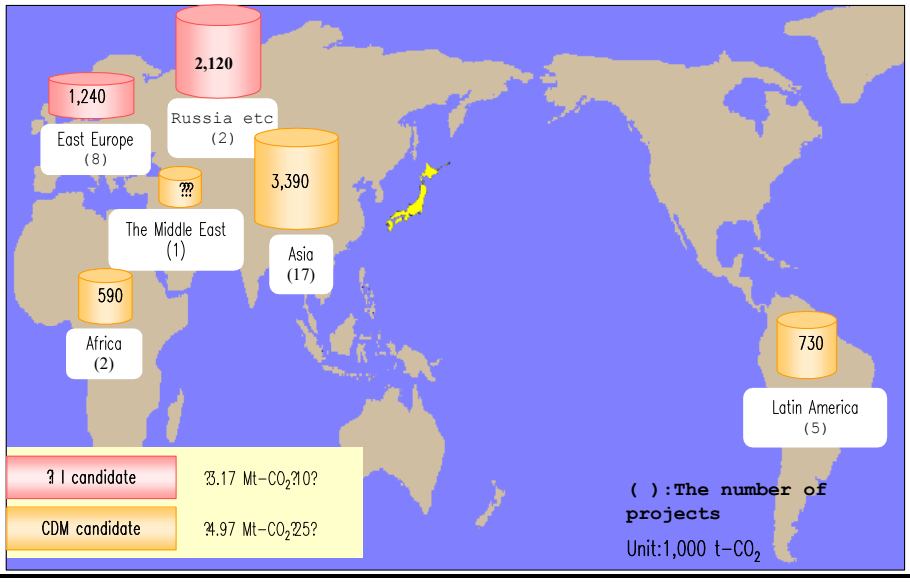
✧ Additionally, the one by private projects of Japanese Steel industry (7) is 900,000t-CO2.

( ):The number of projects



(2) Potential of CO_2 Emission Reduction by International Technology Deployment

The CO2 emission reduction potential is 8.34 million t-CO2 according to the investigation of NEDO.



Japan – General Energy Savings & Environmental Measures

13. Use of Unused Energy in the Vicinity Region

(Outside of Steel Works)

- Heat supply - Promoting energy savings in the community?

Steam generated by the power station is supplied to nearby sake breweries for sake production,including rice steaming,bottle washing and sterilization procedures.The heat supplied from the power station eliminates the need for each brewery to have a boiler,and thus contributes to energy savings.

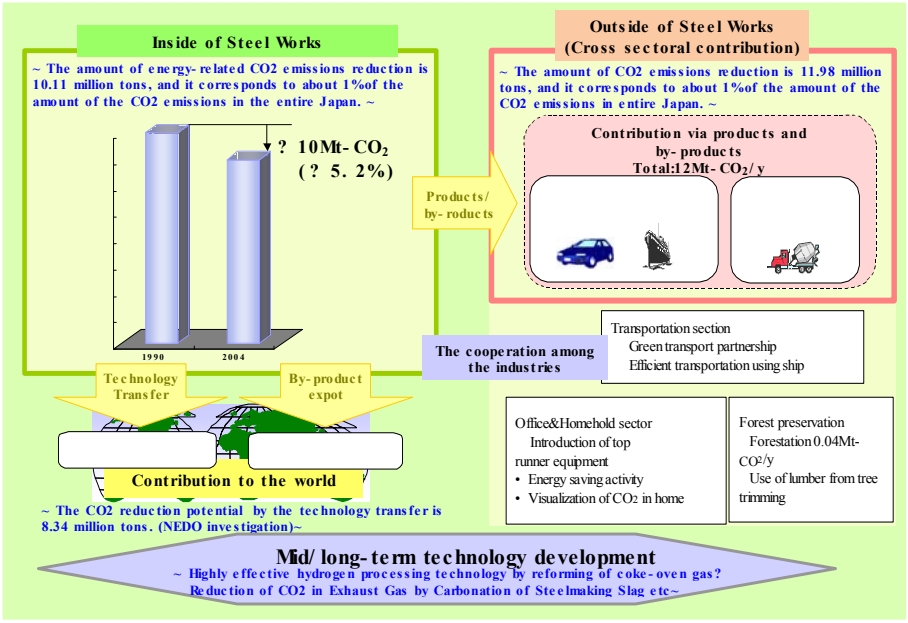


Steam generator

The steam supplied for electricity generation passes through heat exchanger where indirect steam is newly produced.This steam is conveyed to each brewery through piping buried beneath the streets.

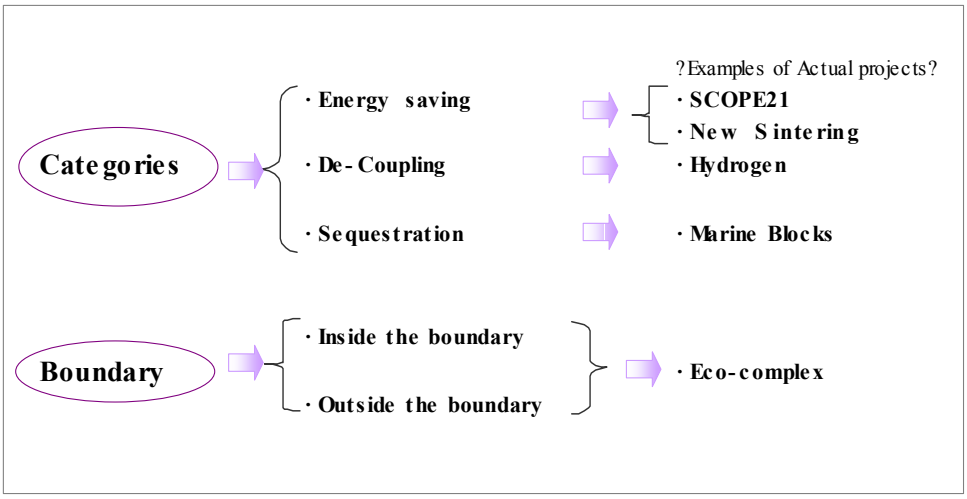
14. Overview of Achievement in Voluntary Action Plan of Japan Steel Industry

(CO_2 Emission Reduction in FY2004)



Japan – General Energy Savings & Environmental Measures

2. About a Mid/long-term, Technological Development



(1) Development of a New Sintering Process for Reducing CO2 Emissions

Background

Drastic reduction of CO2 emission from steel works over 10%

Purpose

Development of partially reduction process in conventional sintering machine
Increase in blast furnace performance by using partially reduced sinter
(high-productivity, high-flexibility)

Proposal process

<Conventional>

Fine ore → Sintering machine → Sinter Fe2O3 → Blast furnace ← Coke oven

<New process>

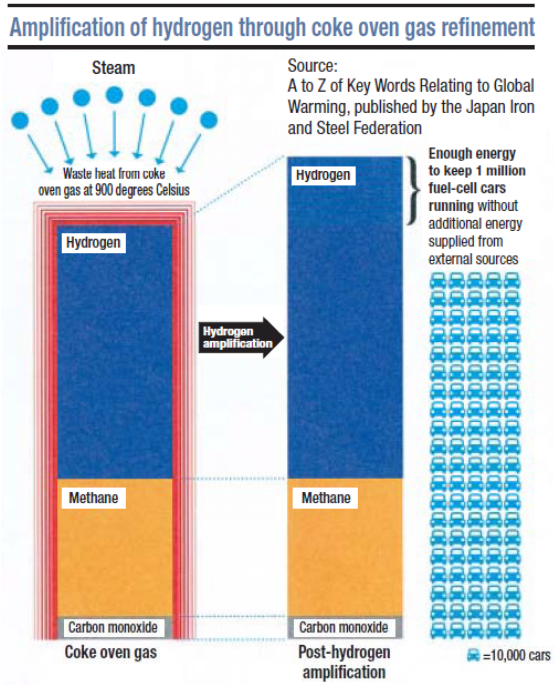
Fine ore → Partially reduction + Sintering → Partially reduced sinter Fe/FeO → High performance blast furnace ← Coke oven

Improvement of handling due to high strength sinter

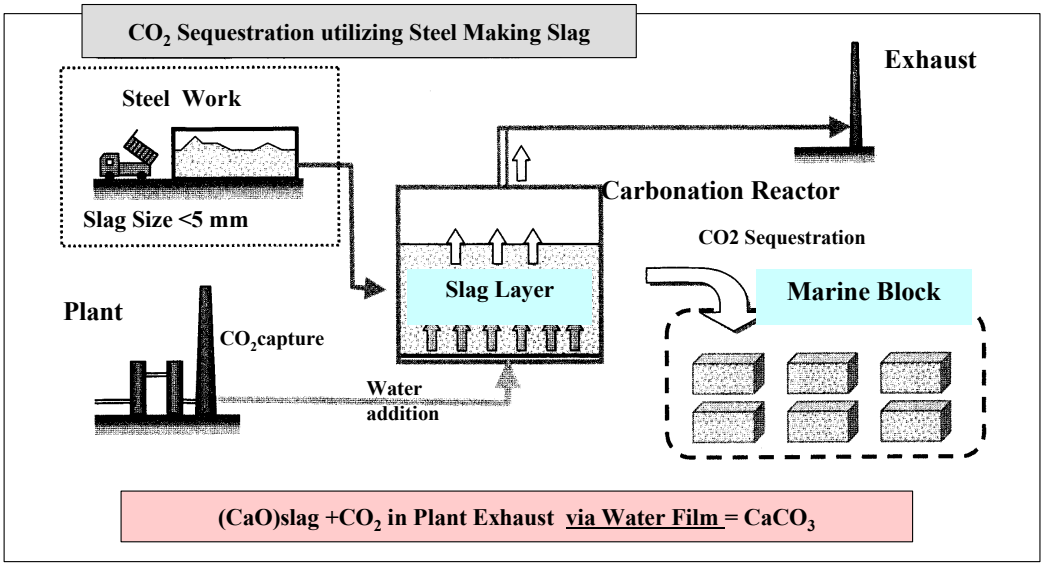
Reduction of CO2 emission

(2) Development of High-efficiency Hydrogen Production Technology

- Verification tests are currently being promoted
- The development of a separation membrane is an important element.
- Production of hydrogen by effectively utilizing 900°C COG exhaust heat without the addition of outside energy



(3) Reduction of CO_2 in Exhaust Gas by Carbonation of Steel Making Slag

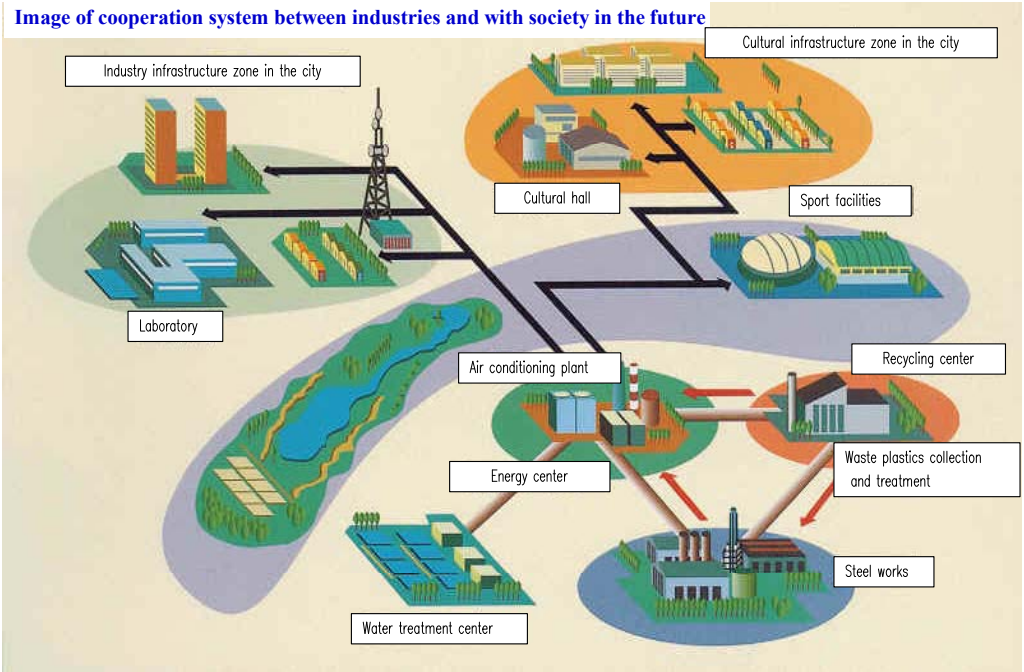


(CaO)slag +CO_2 in Plant Exhaust via Water Film = $CaCO_3$

Japan – General Energy Savings & Environmental Measures

(2) Eco-complex

Image of cooperation system between industries and with society in the future



Conclusion

The Japanese steel industry has promoted energy conservation measures backed by numerous technological developments after experiencing oil crises on two occasions.

In recent years, it has formulated independent action plans for global warming and is continuing to implement activities centered in the Japan Iron and Steel Federation (JISF) and it is proud to have now developed one of the most energy efficient production structures in the world. The steel industry, however, is still an industry that consumes large quantities of energy amounting to 11% of all energy consumed in Japan and all of those involved are strongly aware that, in order to improve energy efficiency further, there is an absolute essential need for constant earnest endeavors.

It is committed to ongoing activities for both business expansion and the global environment through the development and improvement of product processes as well as products from the perspective of collaboration with the outside.
The history of the responses of the steel industry in Japan to energy-related issues that it has experienced thus far should be considered the shared assets of the steel industries in six APP Steel Task Force member countries.

Japan – General Energy Savings & Environmental Measures

Outline of Environmental Policies in Japan

Ministry of Economy, Trade and Industry

1. Regulatory Measures

Relation between Environmental Standard and Emission Standard

- In order to achieve a standard that is desirable to maintain in terms of protecting human health (environmental standard), various emission controls are enforced.
- An example of environmental standards related to the atmosphere

Substance	Environmental conditions
Nitrogen dioxide	Daily average for figures per hour should be within the zone of 0.04ppm to 0.06ppm or less.
Sulfur dioxide	Daily average for figures per hour should be 0.04ppm or less, and figures per hour should always be 0.1ppm or less.
Carbon monoxide	Daily average for figures per hour should be 10ppm or less, and the average of figures per hour for 8 hours should be 20ppm or less.
Airborne particulate	Daily average for figures per hour should be 0.10mg/m^3 or less, and figures per hour should always be 0.20mg/m^3 or less.
Photochemical oxydant	Figures per hour should always be 0.06ppm or less.

Not applicable to restricted industrial zones, carriage ways or other areas and places where the general public do not usually live.

- An example of environmental standards related to water quality (harmful substances)

Substance	Environmental conditions
Cadmium	Annual average should be 0.01mg/L or less.
All cyanogens	Should not be detectable.
Lead	Annual average should be 0.01mg/L or less.
Chromium hexavalent	Annual average should be 0.05mg/L or less.
Arsenic	Annual average should be 0.01mg/L or less.

Emission Control (An Example of the Air Pollution Control Law)

Controlled substance		Example of substances	Emission standard	Regulatory measure
Smoke	Sulfur oxide	• SO2, SO3	• Emission control based on coefficient K, which is set by regions, and the height of outlet (general and special) • Emission control for each specified plant within the specified region based on the plan to reduce the total amount	• Improvement order • Order to take measures when there is an accident
	Smoke dust	• Soot	• Emission concentration regulation set by the type and size of facility (general, special and additional)	• Same as above
	Harmful substances	• Nitrogen oxides	• Emission concentration regulation set by the type and size of facility (general and additional) • Emission control for each specified plant within the specified region based on the plan to reduce the total amount	• Same as above
		• Cadmium and cadmium compounds • Chlorine and chloride compounds • Fluorine, hydrogen fluoride and silicon fluoride • Lead and lead compounds	• Emission concentration regulation set by the type and size of facility (general and additional)	• Same as above
Dust	General dust	• Cement powder, coal powder, iron powder	• Standards on structure, usage and administration	• Order to fulfill standards
	Specific dust	• Asbestos	• Concentration standard at the border of facilities • Operation standards when destroying buildings	• Improvement order
Toxic air pollutant		• Substances with risk (234 substances) • Within above, prioritized substances (22 substances)	• None	• None • (Self control)
	Specified substances	• Benzol, trichloroethylene, tetrachloroethylene	• Emission concentration regulation set by the type and size of facility	• Recommendation and instruction • (Self control)
Volatile organic compound		• Toluene, xylene, and more than 200 other substances	• Emission concentration regulation set by the type and size of facility	• Improvement order • (Self control)

Effluent Regulation on Business Sites with Effluent of 50m^3/day or More

? Environmental standard: Policy target

(1) Health items (harmful substances)
?Uniform standards throughout the nation
?26 items including cadmium are set

?Life environment items
?Set individually by types of waters such as rivers, lakes and seas
?10 items including BOD are set

? Effluent standard: Effluent control measures

(1) Health items (harmful substances)
?Uniformly applied to sewage discharged into public waters
?Applied to all business sites discharging harmful substances
?27 items including cadmium are set

?Life environment items
?Applied to nitrogen and phosphorus only to waters in which there are risks that they may cause notable phytoplankton growth in lakes or seas
?Applied to business sites with average effluent of 50 m3/day or more 15 items including BOD are set

Effluent Standards for Life Environment Items

Life environment items	Maximum permissible level
Hydrogen-ion concentration (PH)	Other than sea area: 5.8-8.6 Sea area: 5.0-9.0
Biochemical oxygen demand (BOD)	160mg/L (Daily average: 120mg/L)
Chemical oxygen demand (COD)	160mg/L (Daily average: 120mg/L)
Suspended solids (SS)	200mg/L (Daily average: 150mg/L)
n-hexane extracts content (liquid petroleum content)	5mg/L
n-hexane extracts content (plant/animal oil and fat content)	30mg/L
Phenolic content	5mg/L
Lead content	3mg/L
Zinc content	5mg/L
Soluble iron content	10mg/L
Soluble manganese content	10mg/L
Chromium content	2mg/L
Coliform count	Daily average: 3,000/cm^3
Nitrogen content	120mg/L (Daily average: 60mg/L)
Phosphorus content	16mg/L (Daily average: 8mg/L)

Pollution Control Manager System

1. Governing law

Law Concerning the Improvement of Pollution Prevention Systems in Specific Factories (Law No. 107, 1971)

2. Purpose of the system

It is necessary for a business entity to establish an effective and appropriate pollution prevention system within the factory in order to comply with regulations related to pollution prevention and to make assurance doubly sure on the prevention of industrial pollution. From such a perspective, in specified factories fulfilling certain conditions, it is obligated to establish a pollution control organization by appointing pollution control supervisors, senior pollution control managers and pollution control managers (hereinafter referred to as the “Pollution Control managers”), and to make notifications to the governor of the prefecture.

Outline of the Pollution Control Manager System

Specified business entities

Businesses covered (4): Manufacturing, electric supplying, gas supplying and heat supplying
Business entities for specified factories having:
?Smoke discharging facility
?Sewage facility
?Noise emitting facility
?Vibration generating facility
?Specified dust discharging facility
?General dust discharging facility
?Dioxin generating facility ?

Appoint

Pollution control managers

1. Pollution control supervisors (No qualification necessary)?
Those who supervise the work related to pollution control in specified factories
2. Senior pollution control managers (Qualification necessary)
Those who assist the pollution control supervisor and technically direct the pollution control managers in specified factories with a smoke discharging facility or sewage emitting facility of certain size .
3. Pollution control managers (Qualification necessary)
Those who are in charge of technical items related to pollution control, such as inspecting the raw materials used in the specified factory and maintaining and managing the pollution generating facilities
4. Those who deputes the above roles
Those who serves the above role when those appointed could not carry out their duties

Notify

Qualify

Governors of prefectures

1. Acceptance of notification
?Appointment and dismissal of pollution control managers
?Succession of the position

2. Report collection and on-the-spot inspection

3. Orders to dismiss pollution control managers

4. Penalties

National government (METI, etc.)

1. National exam
?Conducted by the Minister of Economy, Trade and Industry and the Minister of the Environment
?Testing institutions can be appointed (Japan Environmental Management Association for Industry was appointed in 1987, and it is in charge of administrative services for the test)

2. Qualification courses
?Given by institutions registered by the national government

Qualification requirements for pollution control managers

The following qualifications specified by the category of facility will be necessary:
⁇To pass the national exam on pollution control managers
⁇To complete the qualification courses
(Qualification category) 14 categories in total
?Type 1-4 air pollution control managers
?Type 1-4 water pollution control managers
?Noise pollution control managers
?Vibration pollution control managers
?Specific dust pollution control managers
?General dust pollution control managers
?Dioxin pollution control managers
?Senior pollution control managers

An Example of Pollution Control Organization in Specified Factories

(Example) A factory with a smoke discharging facility and sewage emitting facility, emitting gas of more than 40,000m^3/hour and sewage of 10,000m^3/day

(No qualification necessary)

Pollution control supervisors

(Deputy)
Pollution control supervisors

(Factory manager level)

(Qualification necessary)

Senior pollution control managers

(Deputy)
Senior pollution control managers

(Department or section manager level)

(Qualification necessary)

Type 1 air pollution control managers

(Deputy)
Type 1 air pollution control managers

Type 1 water pollution control managers

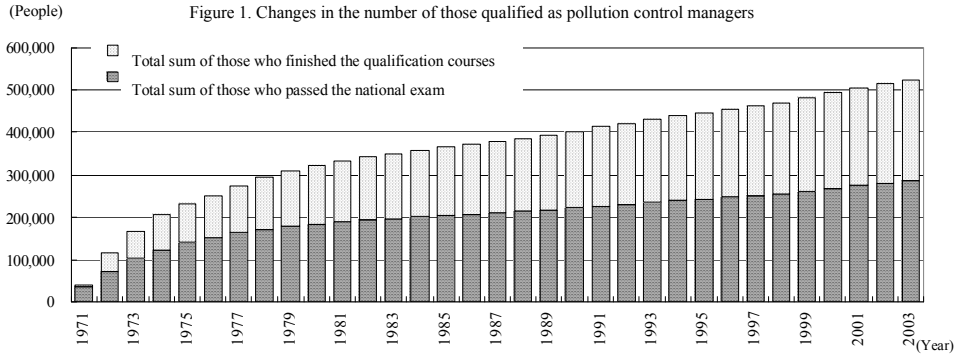
(Deputy)
Type 1 water pollution control managers

(Section manager or unit chief level)

Changes in the Number of Pollution Control Managers

• Many people acquired qualification in the first few years from when the system was established. From then on, the number of those qualified has been increasing at a constant rate.
• The total sum of those qualified as of FY2003 is about 520,000 (about 280,000 came by national exam, and about 240,000 by qualification courses).

Figure 1. Changes in the number of those qualified as pollution control managers

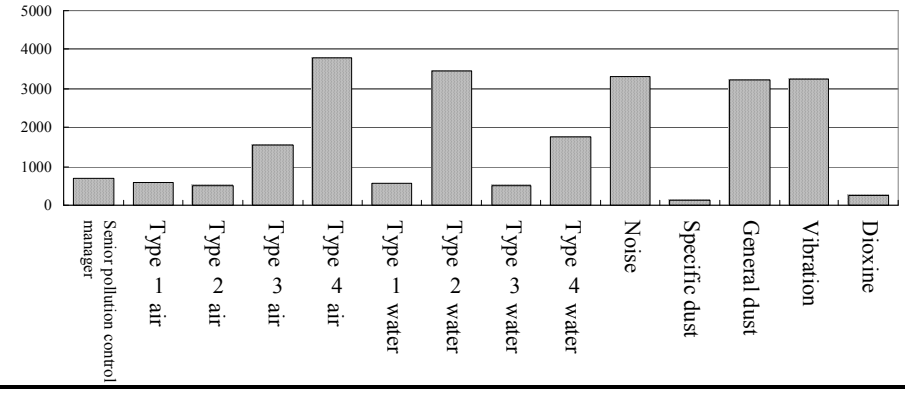


Japan – General Energy Savings & Environmental Measures

Number of Factories that Notified the Appointment of Pollution Control Managers

• The Number of factories that submitted the notification of appointment as of the end of FY2002 was about 24,000.
• Among them, type 4 air pollution control managers holds the largest share (about 3,700 factories), followed by type 2 water pollution control managers (about 3,500 factor

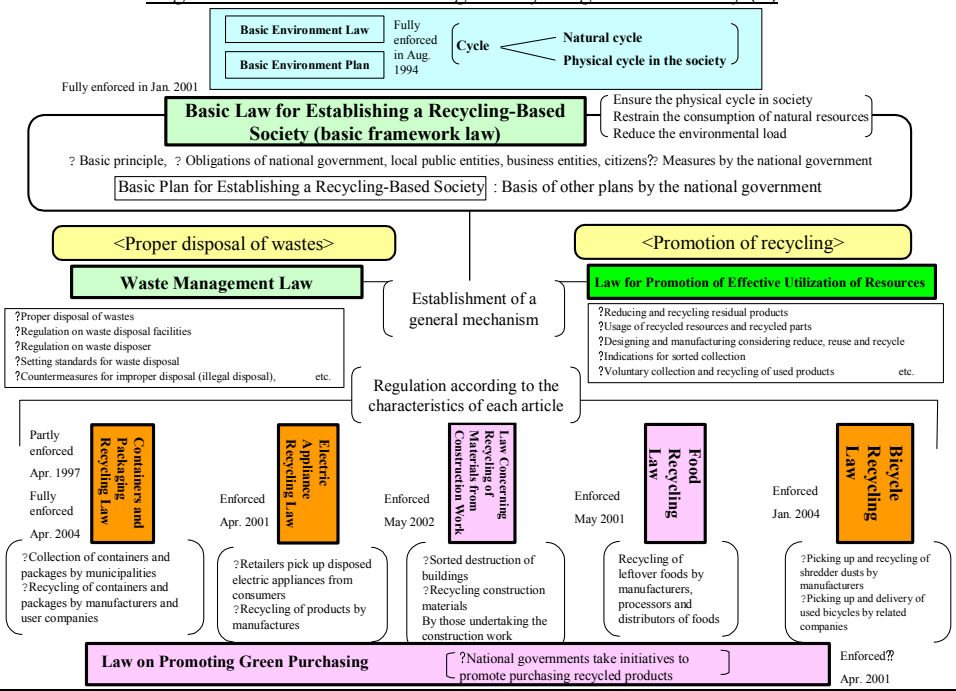
Figure 2. Number of factories that notified the appointment



2. Recycling Law

Japan – General Energy Savings & Environmental Measures

Legal Structure for Establishing a Recycling-Based Society (1)



Japan – General Energy Savings & Environmental Measures

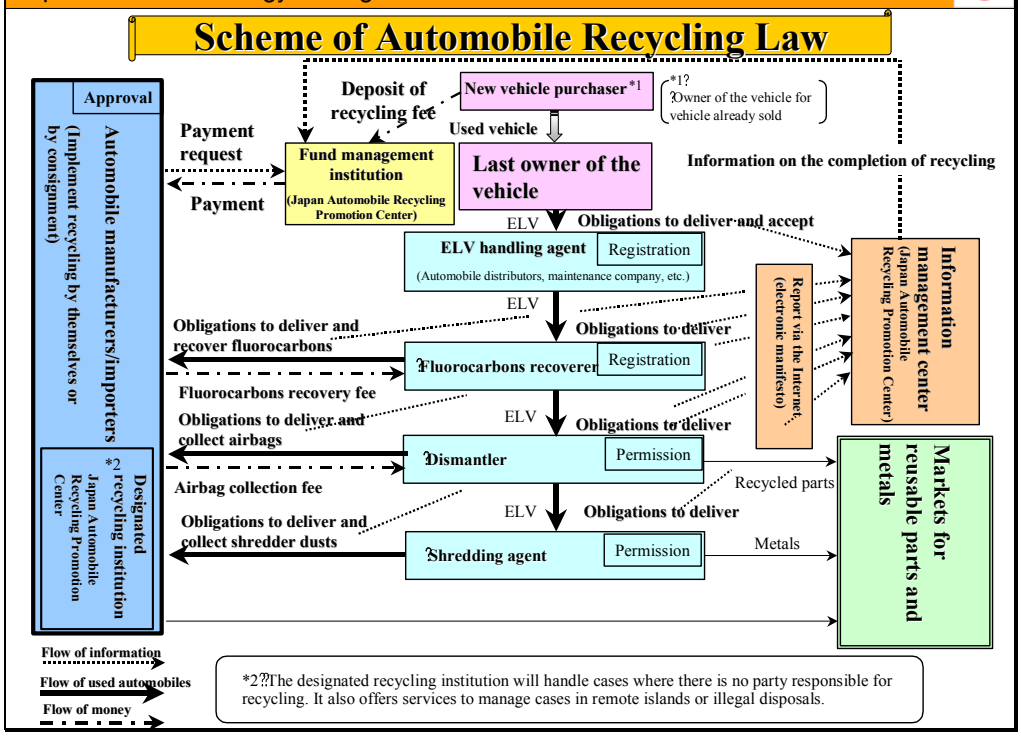
Legal Structure for Establishing a Recycling-Based Society (2)

Lifecycle of products	Legislation related to recycling	Major roles of involved parties
Production	Law for Promotion of Effective Utilization of Resources	**Business entities** ? Environment-conscious designing (resource saving/longer life) ? Promotion of recycling/reusing ? Indication of materials
Consumption/usage	Law on Promoting Green Purchasing	**Governments** ? Taking initiatives to purchase environment-conscious products
Collection/recycling	Law for Promotion of Effective Utilization of Resources Containers and Packaging Recycling Law Electric Appliance Recycling Law Food Recycling Law Law Concerning Recycling of Materials from Construction Work Bicycle Recycling Law	**Business entities** ? Voluntary collection **Consumer** ? Proper emission (sorted emission) ? Proper expense distribution
Disposal	Waste Management Law	**Business entities and municipalities** ? Proper waste disposal

Basic Law for Establishing a Recycling-Based Society (basic framework law)

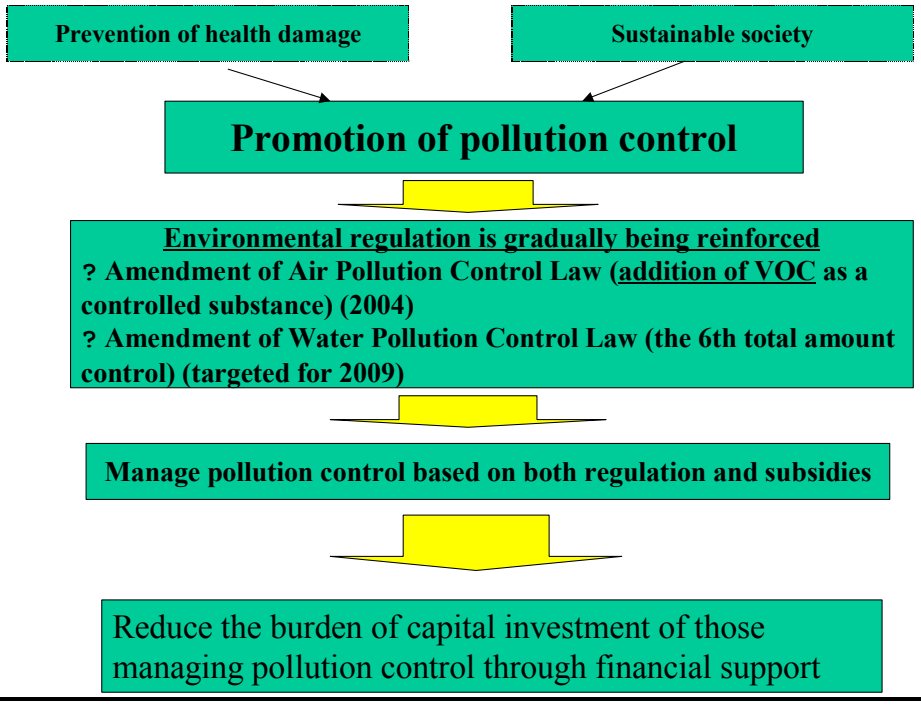
Japan – General Energy Savings & Environmental Measures

Scheme of Automobile Recycling Law



3. Supporting Measures

(Pollution Control Taxation/National Investment and Loan Program)



Preferential Treatment System Related to Pollution Control Investments

- Tax privileges

National tax: Special depreciation of income tax/corporate tax (10% or 14%) on the first fiscal year of installing the equipment

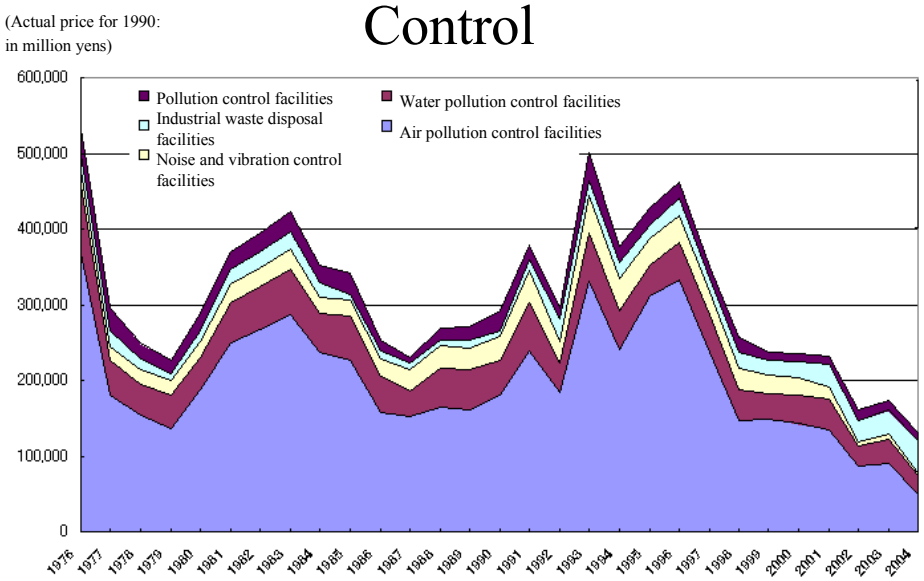
Local tax: Exceptional treatment on the tax base for fixed property tax (exceptional treatment of one sixth to two thirds depending on the equipment)

Deduction of asset allocation in business office tax (three quarters

- National investment and loan program

Low interest loan system through the Development Bank of Japan, Japan Finance Corporation for Small Business and National Life Finance Corporation

Amounts of Investment for Pollution Control



Environmental Improvements in Japan

- Air pollution

Sulfur oxide concentration: 1974: 0.0173ppm ? 2003: 0.0040ppm (-77%)
SPM: 1974: 0.0792ppm ? 2003: 0.0274ppm (-65%)
Nitrogen oxides (NOx): 1972: 0.0655ppm ? 2003: 0.0344ppm (-47%)

- Water pollution

Pollution loading amount based on the total water pollutant control plan
1984: 551t/day ? 2003: 414t/day (-25%)

- Dioxin

Total amount of emission 1997: 8135g-TEQ? 2003: 404g-TEQ (-95%)

Japan – General Energy Savings & Environmental Measures

Special Depreciation System for National Tax (Reference)

Structures: Special depreciation rate of 10%

- Sewage treatment facility (tank)
- Smoke treatment facility (chimney)

Machinary and equipment: Special depreciation rate of 14%

- Sewage treatment equipment
- Smoke treatment equipment
- Dioxin emission controlling equipment
- Nitrogen oxides controlling equipment
- Equipment to recover specified substances
- Industrial waste disposal equipment
- PCB pollutant treatment equipment
- Equipment to control the emission of volatile organic compounds

Preferential Treatment on Fixed Property Tax and Business Office Tax (Reference)

- Fixed property tax

Tax base one sixth: Slag, mine water, wastewater or metallurgical smoke treatment facilities, sewage or waste liquid treatment equipment, smoke treatment equipment, waste PCB treatment equipment, industrial waste incineration or dissolution facility, equipment to control the emission of volatile organic compounds

Tax base one third: Equipment to control the emission of specified substances, industrial waste disposal facility, dioxin emission controlling facility, groundwater remediation facility, soil remediation facility

Tax base half: waste oil and waste plastics disposal facilities

Tax base two thirds: facility to improve the combustion of nitrogen oxides, exceptional facilities, facility to dispose shredded articles including automobiles, industrial waste incineration facility, smoke treatment facility (chimney), good replacement investment facility (some are half)

- Business office tax (three quarters deduction of asset allocation)

  Slag, mine water, wastewater or metallurgical smoke treatment facilities, sewage or waste liquid treatment equipment, smoke treatment equipment, facilities to control the emission of volatile organic compounds, specified substance treatment facility, industrial waste disposal facility, dioxin emission reducing facility

National Investment and Loan Program (Reference)

Development Bank of Japan

- Air pollution controlling facility maintenance, sewage treatment facility maintenance, noise controlling facility maintenance, foul odor controlling facility maintenance, vibration control facility maintenance, waste disposal facility

  (Policy interest rate II (Policy interest rate III for medium and small sized companies))

Japan Finance Corporation for Small Business and National Life Finance Corporation

- Smoke treatment facility, sewage treatment facility, industrial waste disposal facility, dioxin emission reducing facility, cost for entrusted treatment of waste PCB, facility to prevent soil contamination

  (Special interest rate 3; exceptional treatment systems on warranties and guarantors can be used for the Japan Finance Corporation for Small Business)

Overview of the Energy Conservation Policy of Japan

Ministry of Economy, Trade and Industry

Japan – General Energy Savings & Environmental Measures

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1. Situations Surrounding Energy Consumption in Japan
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   2) Change in energy consumption by sector

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   2) Energy conservation measures in the industrial sector
   3) Energy conservation measures in the commercial/residential sector
   4) Energy conservation measures in the transportation sector
   5) Development of energy-saving technology

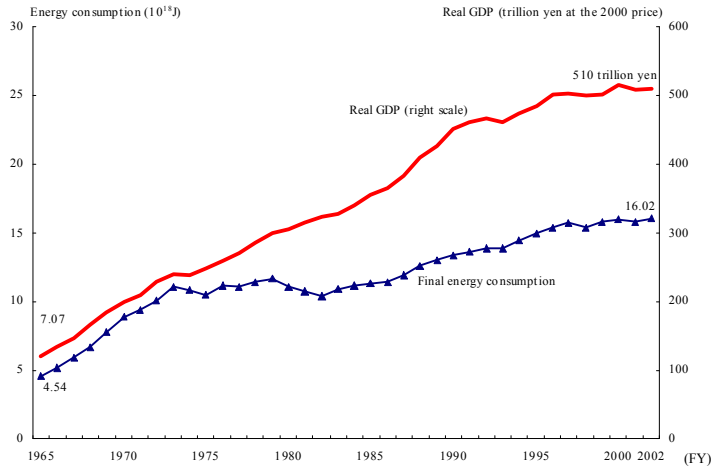
3. References

1. Situations Surrounding Energy Consumption in Japan

Japan – General Energy Savings & Environmental Measures

Energy Demand and Economic Growth in Japan

• Growth in energy consumption in Japan has been lower than economic growth.



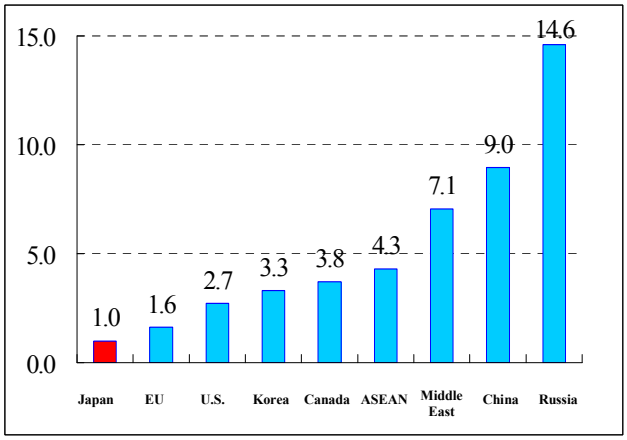
Source: Agency for Natural Resources and Energy, Comprehensive Energy Statistics; Institute of Energy Economic, Japan, Handbook of Energy and Economic Statistics

Note: In the Comprehensive Energy Statistics, the calculation method has been partially changed for data for 1990 and thereafter, e.g. calculating the final energy consumption on the demand side instead of the supply side.

I-1. Overall Status

Primary Energy Consumption per GDP

○ Japanese primary energy consumption per GDP is the lowest in the world owing to various energy conservation measures taken for the respective sectors.



Source: IEA Energy Balance 2004

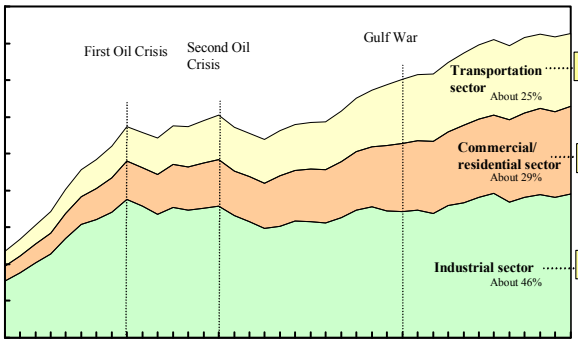
(Note) Primary energy consumption (tons in oil equivalent)/GDP (thousand US$) indicated in the ratio when the Japanese figure is set at 1.

Change in Energy Consumption in Japan by Sector

- Energy consumption in the industrial sector has remained relatively level because of advanced energy consumption measures and the changes in industrial structures.
- Energy consumption has significantly increased in the commercial/residential and transportation sectors.

Growth in energy consumption (FY1973-FY2002)

(million kl in oil equivalent)



Source: Comprehensive Energy Statistics

?Transportation sector: Passenger transport and cargo transport
?Energy consumption for road transportation (passenger/freight cars), railways, navigation, and civil aviation

?Commercial/residential sector
?Residential sector: Energy consumption for air conditioning, cooking, boiling, lighting, and other power consumption; consumption for private cars is included in the transport sector data.
?Commercial sector: Energy consumption for office buildings, stores, restaurants, hotels, hospitals, and other commercial facilities (except for those in the industrial or transport sector); energy consumption for cargo transport is included in the transport sector data.

?Industrial sector: Energy consumption for primary and secondary industries (agriculture, forestry, fisheries, mining/construction, manufacturing)

Gist of the Kyoto Protocol Target Achievement Plan

Target

?Ensure 6% reduction commitment under the Kyoto Protocol

? Steady implementation of a continuous as well as long-term GHG emissions reduction on a global scale

Basic Idea

?Integration of the environment and the economy

?Promotion of technological innovation

? Promotion of participation and collaboration by all the stakeholders

? Utilization of various policy measures

? Prioritization of the evaluation and review process

? Ensuring international collaboration

Targets of GHG reduction/absorption

GHGs	Target: Emissions in FY 2010 (million tons-CO_2)	Target: Compared to FY 1990 (Total emission over the base year)	Projected reduction in FY 2010 under existing measures (+12%*) * Total reduction with projected increase caused by economic growth and reduction by existing measures over actual achievement in FY2002 (+13.6%)
a. Energy related CO_2	1,056	+0.6%	-4.8%
b. CO_2 from Non-energy sources	70	-0.3%	-0.4%
c. Methane	20	-0.4%	
d. N_2O	34	-0.5%	
e. Other GHGs	51	+0.1%	-1.3%
Sink including forests	-48	-3.9%	-3.9%
Kyoto Mechanism	-20	-1.6%*	-1.6%
Total	1,163	-6.0%	-12%

*Difference between reduction target (minus 6%) and domestic measures

Policy measures to accomplish the target

1. Policies and measures on GHGs emissions reduction and sinks

(1) GHGs emissions reduction

?a. Energy related CO_2?

??Promote measures on energy related apparatus as well as on individual facility/stakeholder

??Take measures to shift socio-economy including urban/regional structure and public transportation infrastructure into low carbon one

?b. CO_2 from non-energy sources

??Promote the use of blended cement

?c. Methane

??Reduction of final disposal volume

?d. N_2O

??Improvement of incineration process in incineration facility for sewage sludge and municipal solid waste

?e. Other GHGs (HFC, PFC, SF6)

??Promote systematic actions by industries and development and use of alternatives

(2) GHG Sinks

??Develop healthy forests

??Promote greening through public participation

(3) Kyoto Mechanism

??Promote overseas emission reduction projects

2. Cross-sectoral measures ?Public awareness raising campaign ? Initiatives by public institutions ? GHG accounting, reporting and announcement ? Policy mix

3. Basic measures ?Domestic system to account GHG emissions and absorption ? Promotion of technology development and R&D ? Promotion of international collaboration and cooperation

Organizational arrangements

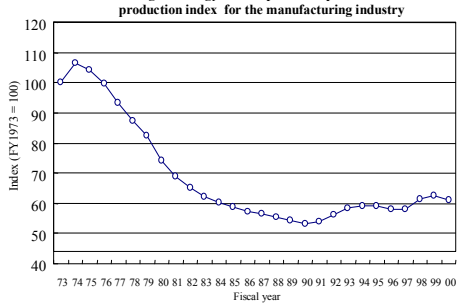
?Annual review and quantitative assessment of the Plan in FY 2007? ? The Headquarters will take the lead in steadily implementing the Plan

Japan – General Energy Savings & Environmental Measures

Change in Energy Consumption in the Industrial Sector

- Energy consumption in the industrial sector has been generally steady since oil crisis.
- Energy consumption unit per industrial production index for the manufacturing industry suffered a sharp fall through to the 1980s, but has been on a trend of slight increase since the 1990s.
- Japan's energy consumption unit against GDP in the industrial sector is lower than those of other major countries.

Change in energy consumption unit per industrial production index for the manufacturing industry

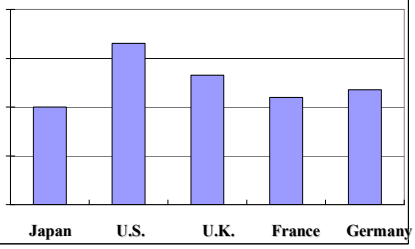


?Source?General energy statistics, annual report on industrial indices

Note 1: The industrial production index is weighted with value added structure (1995 standard).

Note 2: Since the industrial production index is affected by sales values, when a sales price drops, the index may go below the index of production volume.

Unit Energy Consumption per GDP in the Industrial Sector by Country



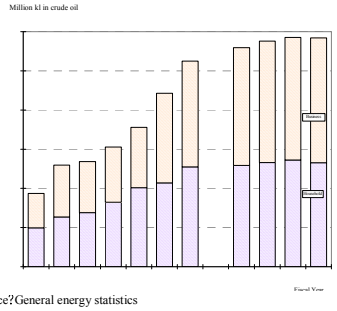
*Final energy consumption (tons in oil equivalent) / real GDP (1995 value in US$) (both are actual figures for FY2000), indicated in the ratio when the Japanese figure is set at 1.

Source: Compiled by the Natural Resources and Energy Agency based on energy & economic statistics data

Change in Energy Consumption in the Commercial/Residential Sector

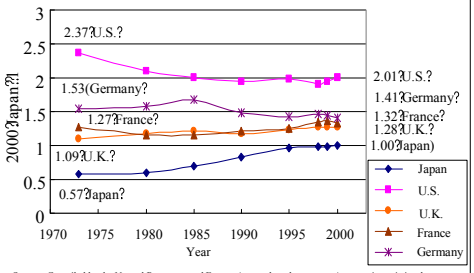
- Energy consumption in the commercial/residential sector surged after the oil crisis and is still on the growth trend in recent years.
- Japan's per-capita energy consumption in the commercial/residential sector is relatively low compared to other major countries, but the difference is narrowing down.

Change in energy consumption in the commercial/residential sector



?Source?General energy statistics

Change in Energy Consumption per Capita in the Commercial/Residential Sector



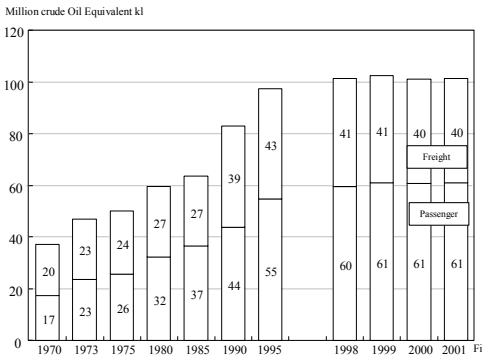
Source: Compiled by the Natural Resources and Energy Agency based on energy / economic statistics data

Japan – General Energy Savings & Environmental Measures

Change in Energy Consumption in the Transportation Sector

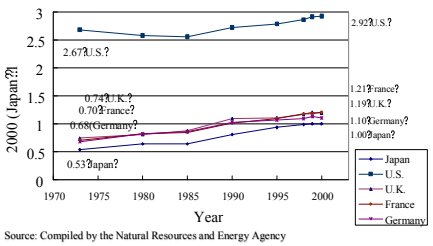
- Energy consumption in the transportation sector surged after oil crisis and has leveled off in recent years.
- Per-capita energy consumption in the transportation sector is on the increase in all major countries.

Change in energy consumption in the transportation sector



Source: General Energy Statistics

Change in per-capita energy consumption in the transportation sector



Source: Compiled by the Natural Resources and Energy Agency based on energy / economic statistics data

2. Energy Conservation Measures by Sector

Three Pillars of Energy Conservation Measures

Regulation (Energy Conservation Law)

<Measures for factories and business establishments>
- Measures for factories with high energy consumption
- Periodical reports on the status of energy use
- Submission of a future plan for energy conservation
- Appointment of an energy manager

<Measures for buildings>
- Notification of energy conservation measures for buildings of a certain size

<Measures for machinery and equipment>
- Introduction of the Top Runner Program

Promotion (subsidies, taxes, fiscal investment)

<Encouraging enterprises and local governments to introduce energy-saving equipment>
- (1) Support programs and model projects for the introduction of energy-saving equipment
  - Promote the use of energy management systems in residences and buildings
  - Support ESCO business
  - Promote the introduction of high-efficiency water heaters
- (2) Special depreciation and tax credit for the introduction of energy-saving equipment
- (3) Low-interest loans for the introduction of energy-saving equipment
- (4) Other grants (community support)

<Development of energy-saving technology>
- Support for the development of energy-saving technology
  - Technology development in the public sector
  - Technology development in the private sector

Promote energy conservation by the three core measures

Information provision (publicity, labeling, education)

<Publicity, advisory services>
- (1) Dispatch experts who can provide advice on energy conservation
- (2) Distribute catalogues of energy-saving products

<Labeling>
Labeling system to indicate the energy conservation standard achievement rate of appliances

<Education>
Promote education on energy conservation at elementary and junior high schools

Overview of the Law Concerning the Rational Use of Energy (Energy Conservation Law)

The purpose of the Energy Conservation Law is:
To the end of ensuring the effective use of fuel resources, to implement the necessary measures for the rational use of energy in factories, buildings, and machinery and equipment, thereby contributing to the sound development of the national economy.

- **Measures for factories and business establishments**
  - Factories and business establishments with high energy consumption (Type 1 Designated Energy Management Factories)
    - Appointment of an energy manager
    - Submission of mid and long-term plans
    - Periodical reports
  - Factories and business establishments with medium energy consumption (Type 2 Designated Energy Management Factories)
    - Appointment of an energy officer
    - Participation in periodical training
    - Periodical reports
- **Measures for buildings**
  - Designated buildings (non-residential buildings with a floor area of 2,000 m^2 or more)
    - Notification of energy conservation measures for buildings of a certain size
- **Measures for machinery and equipment** **(Top Runner Program)**
  - Publication and indication of the evaluation criteria
    - Collection of reports
    - On-site inspection

Measures for Factories and Business Establishments under the Energy Conservation Law (1)

- Under the Energy Conservation Law, the concerned factories and business premises are required to report on the status of energy use periodically, formulate and submit mid and long-term plans to achieve the objective of energy conservation, and appoint a certified energy manager, so as to promote planned and independent energy management.
- The Energy Conservation Law was amended in FY2002 to strengthen energy management in the commercial sector where there was a significant growth in energy consumption.
- In order to further strengthen regulations, a bill for the amendment of the Energy Conservation Law has been submitted to the current session of the Diet.

Factories/business establishments with high energy consumption ?Type 1 Designated Energy Management Factories?

- Annual fuel (thermal) use: At least 3000kl in crude oil equivalent
- Annual electricity use: At least 12 million kwh

Factories/business establishments with medium energy consumption ?Type 2 Designated Energy Management Factories?

- Annual fuel (thermal) use: At least 1500kl in crude oil equivalent
- Annual electricity use: At least 6 million kwh

Factories

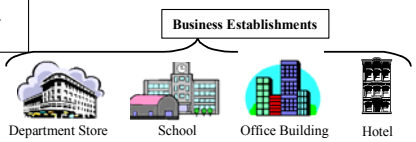
Measures
- Appointment of Energy Manager
  (Mandatory to possess Energy Manager License)
- Preparation & Submission of Periodical Reports
- Formulation & Submission of Mid- and long- term Plans

Business Establishments

Measures
- Appointment of Energy Manager
  ?Energy Manager Training Required?
- Preparation & Submission of Periodical Reports
- Preparation and Submission of mid- and long-term plans (Participation of a Qualified Energy Management Officer Required)

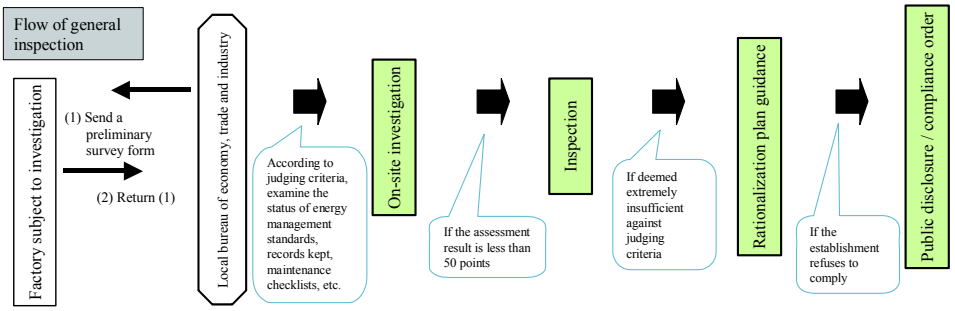
Factories and business establishments

Measures
- Appointment of Energy Management Officer
- Preparation & Submission of Periodical Reports



Measures for Factories and Business Premises under the Energy Conservation Law (2)

- On-site investigation (factory inspection) has been conducted since FY2001 on Type 1 Designated Energy Management Factories.
- Compliance to the factory/business establishments standards is investigated to assess the need for guidance based on objectively set criteria.
- Establishments that have an extremely poor level of energy use rationalization are instructed to prepare/submit a rationalization plan, implement the rationalization plan, and take other relevant steps.



Improving Equipment Efficiency with the Top Runner Program

- The Top Runner Program aims to improve the energy-saving performance of vehicles and electric appliances, beyond the highest level achieved so far for relevant products currently on the market, by the target fiscal year set for each type of appliance.

Energy-Conservation Target for Specific Equipment

Specific Equipment	Target-setting fiscal year	Target Year	Energy conservation effects
Passenger vehicles (Gasoline and LP gas)	1998	2010	Gasoline 23% LP gas 11.4%
Passenger vehicles (diesel)	1998	2005	15%
Freight vehicles (gasoline)	1998	2010	13%
Freight vehicles (diesel)	1998	2005	7%
Air conditioners (cooling & heating)	1998	2004 (Partly 2007)	63%
Air conditioners (cooling only)	1998	2007	14%
TV sets	1998	2003	16%
Video cassette recorders	1998	2003	59%
Fluorescent lights	1998	2005	17%
Copying machines	1998	2006	30%
Computers	1998	2005	83%
Magnetic disc units	1998	2005	78%
Electric refrigerators / freezers	1998	2004	30%

The energy conservation effect is as compared with that of 1997 (and as compared with 1995 for automobiles, and 1998 for electric refrigerators / freezers).

Space heaters	2002	2006	(Gas)1%/(Oil)4%
Gas cooking appliances	2002	2006	14%
Gas water heaters	2002	2006	4%
Oil water heaters	2002	2006	4%
Electric toilet seats	2002	2006	10%
Vending machines	2002	2005	34%

Energy conservation effects in comparison with FY2000 against FY1999 figures for transformers?

Note: With respect to equipment that has reached the target fiscal year, the standards will be reviewed and the scope of designated equipment will be expanded.
For instance, as for TV sets that reached the target fiscal year in FY2003, LCD TV sets and plasma TV sets will be included in the scope of designated equipment, in addition to CRT TV sets, by the end of FY2005.

Examples of Support Programs for Energy Conservation Measures

• Intensive support is provided for investments in energy conservation projects that are highly cost-effective and significant from the policy perspective.

•Support Program for Enterprises Engaging in Rationalized Energy Use

[13.81 billion yen ? 20.29 billion yen]
Provide intensive support for investments in energy conservation projects that are highly cost-effective and significant from the policy perspective, such as large-scale energy conservation projects involving multiple entities (industrial complexes), the first production that achieves a large energy-saving effect in the industry, and industrial furnaces with high energy-efficiency.

•Interest Subsidy Program for Finance for Designated Equipment Engaging in Rationalized Energy Use

[170 million yen ? 120 million yen]
In order to reduce initial costs and promote the introduction of Top Runner equipment, the Development Bank of Japan, among others, using interest subsidies granted by the government, provide low-interest loans for lease businesses that purchase and lease Top Runner equipment.

Japan – General Energy Savings & Environmental Measures

Outline of the Taxation System for Promotion of Investment in Reforms of Energy Supply-Demand Structure (Energy Reform Taxation)

?In this difficult energy situation, in order to ensure sustainable economic development while taking appropriate measures for environmental preservation to cope with global environmental issues, it is critically important to further promote the introduction of oil alternatives and new energy sources, as well as the implementation of measures for electric load leveling, and to this end, it is necessary to encourage the introduction of equipment necessary for energy reforms.
?Since such equipment requires more initial costs than conventional equipment, tax support will be provided to reduce such costs in a direct and fair manner.

Scheme

Enterprises that acquired the designated equipment and used it for commercial purpose within one year from acquisition may choose either of the following:

(1) Tax credit equivalent to 7% of the standard acquisition price (only available to SMEs)
(2) Special depreciation with a limit of 30% of the standard acquisition price, in addition to ordinary depreciation

Designated equipment

(1) Energy-efficient production equipment
(2) Energy-efficient accessory equipment
(3) Electricity/gas demand leveling equipment
(4) Equipment powered by new energy sources
(5) Equipment powered by oil alternatives
(6) Electric supply multiplexing equipment

Standard acquisition price		
?Category		
General	Energy-efficient production equipment	100?
	Energy-efficient accessory equipment	100?
	Electricity/gas demand leveling equipment	50?
	Equipment powered by new energy sources	100?
	Electric supply multiplexing equipment	50?
SMEs	Energy-efficient equipment	100?
	Equipment powered by oil alternatives	100?

Energy-Saving Labeling System

- The "Energy-Saving Labeling System" is designed to encourage voluntary efforts by appliance stores and other parties concerned to indicate, on the appliances subject to the energy conservation standards under the Top Runner Program or catalogues of such appliances, the standard achievement ratio and the annual power consumption of those appliances, so as to help consumers easily understand their energy-saving performance.
- Currently, 13 types of appliances are covered by the labeling system: air-conditioners, fluorescent lights, TV sets, electric refrigerators, electric freezers, space heaters, gas cooking appliances, gas water heaters, oil water heaters, electric toilet seats, computers, magnetic disk units, and transformers.

Examples of energy-saving labeling

	Energy conservation standard achievement percentage	Annual power consumption
Target year FY2004	155%	250kWh/year
Target year FY2004	80%	690kWh/year

Note: Appliances that have achieved the energy conservation standards are labeled with a green symbol, and those that have yet to achieve the standards are labeled with an orange symbol.



Label for the product's main unit

Japan – General Energy Savings & Environmental Measures

Energy Efficient Product Retailer Assessment System

- In order to promote energy efficient products, it is essential to introduce measures for "retailers", who make the contact point between manufacturers and consumers.
- Recognition should be extended to retailers that actively promote energy efficient products or provide appropriate energy conservation information.
- The energy efficient product retailer assessment system was introduced in FY2003.

Logo



- System targets

(1) Large home appliance retailers
Floor space of at least 500 m^2
At least 50% of sales coming from home appliances

(2) Small and medium-sized home appliance retailers
Floor space of 500 m^2 or less
At least 50% of sales coming from home appliances

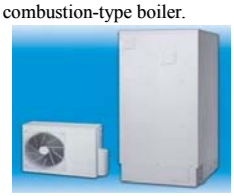
- "Top energy efficient product promotion stores" are selected each year and publicized.
- Stores selected as top retailers are authorized to carry a special logo.

Promotion of High-Efficiency Boilers

- Energy demand for hot-water supply dominates about 30% of the total energy consumption in a household.
- A subsidy system has been introduced to promote the proliferation of energy efficient hot-water systems.

CO_2 Refrigerant Heat-pump Boiler

Utilizing the principle of a heat pump used in an air-conditioner, it can be heated with energy of about 3 times more than input energy. This realized energy saving of about 30% compared to traditional combustion-type boiler.



Latent-heat Recovery Boiler

It recovers latent heat of exhausted gas, which was usually wasted. This realized energy saving of about 15% compared to a conventional combustion-type boiler.



Gas Engine Boiler

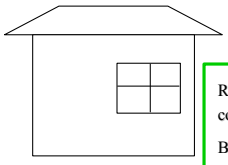
Use the gas-powered engine's exhaust heat and power to provide heat (main) and electricity (sub) for approx. 10? overall energy saving for a building.



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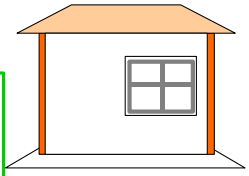
Promotion of High Energy-Efficiency REsidences and Buildings

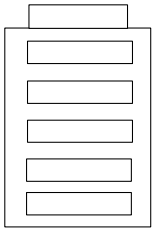
- The Energy Conservation Law was amended in 2002 to require the owners of designated buildings (non-residential buildings with a floor area of at least 2,000 m2) to submit energy conservation measures.
- The labeling of energy conservation performance is promoted.
- Support programs are implemented for residences and buildings that satisfy the standards.

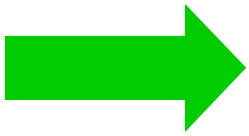


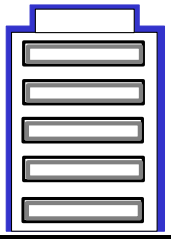
Residences: From FY2008, the rate of energy-saving standard conformity to build new residences shall be set above 50%.

Building: From FY2006, the rate of energy-saving standard conformity to build new buildings shall be set above 80%.









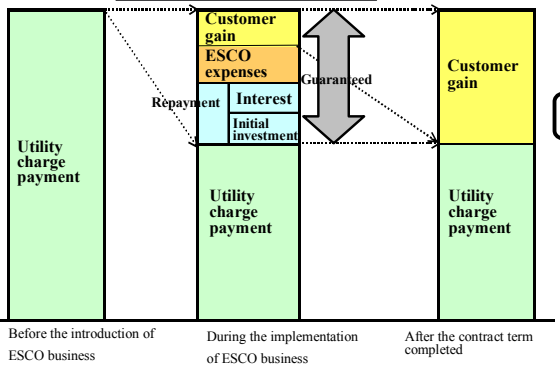
Promotion of ESCO Business

What Is the ESCO Business?

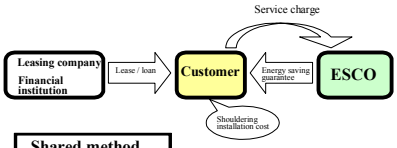
- A business that offers comprehensive services on energy conservation to clients, who in return will offer a part of their energy saving gains (saving on utility bill, etc.)
- The business has two forms: "Guaranteed savings agreement" where customers cover business costs and "Shared savings agreement" where the ESCO business covers business costs. These options enable service provision according to customer needs.

***ESCO stands for Energy Service Company.**

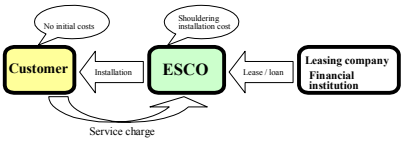
Overview of the ESCO business



Guaranteed method



Shared method



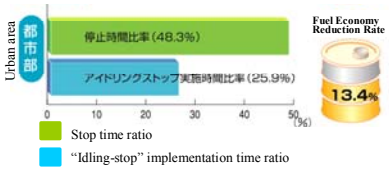
Promotion of Cars with the "Idling-Stop" System

- Idle-free driving can improve fuel economy by approx.10%.
- Even greater energy conservation effect is expected in city areas, where idling frequency is high.
- Partial subsidy for the purchase of cars equipped with the "idling-stop" system was introduced in FY2003.
- Promotion campaigns for the "idling-stop" systems are held in the forms of PR events, etc.

Effects of the driving experiments by "idling-stop" cars

Results of "The Idling-Stop 2002 Caravan throughout Japan"

Nationwide (3719km)… 5.8% on average
Or 13.4% in city areas
[The stop & "idling-stop" implementation time ratio in city area]



PR activities

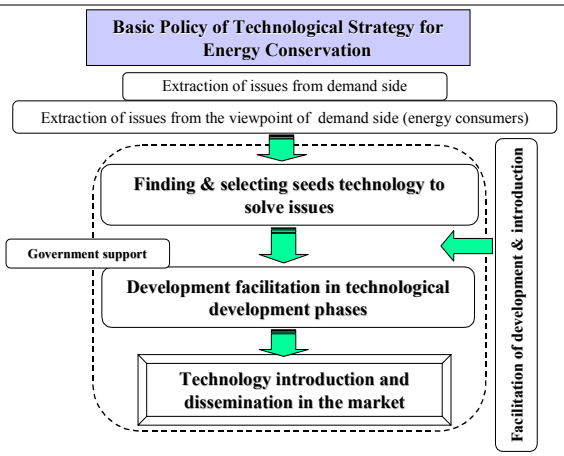
In October 2003, an event for "idling-stop" experiments took place at Tokyo's Ginza and Osaka's Shinsaibashi traffic lights.



Idling-free promotional event (Osaka)

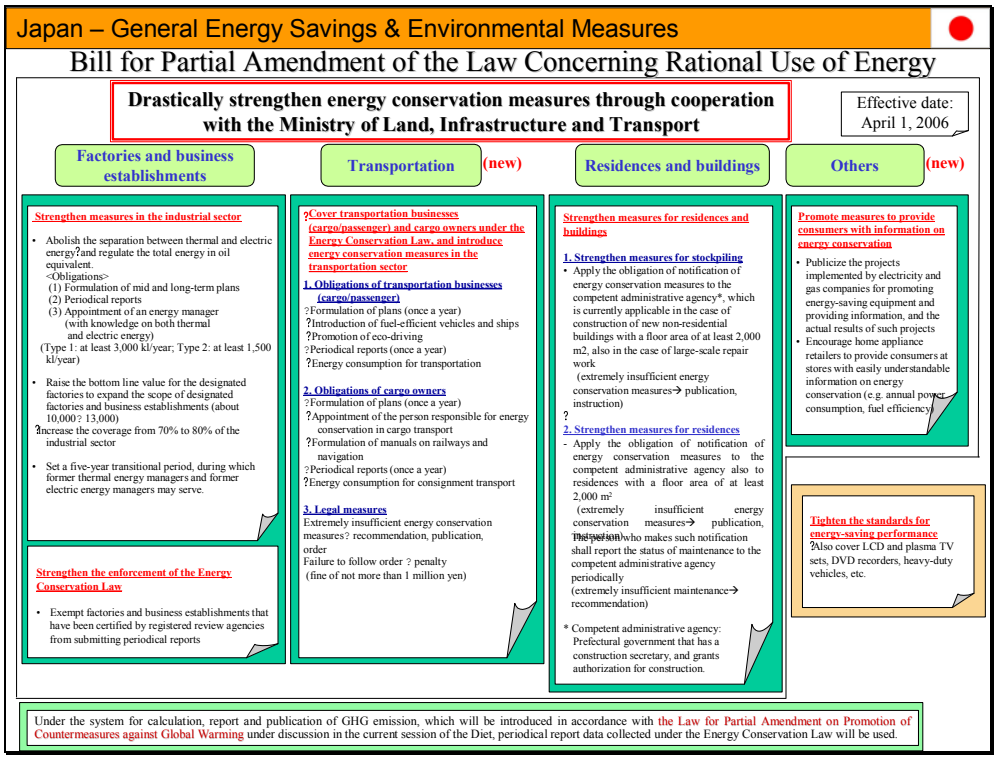
Promotion of Technological Strategy for Energy Conservation

- In June 2000, the "Energy Conservation Technological Strategy" was outlined to clarify the direction of technologies for solving demand side issues.
- By broadly soliciting from the public (private organizations) seeds technologies and verification trials, intensive support is provided for the development of energy conservation technology in line with the Energy Conservation Technological Strategy.

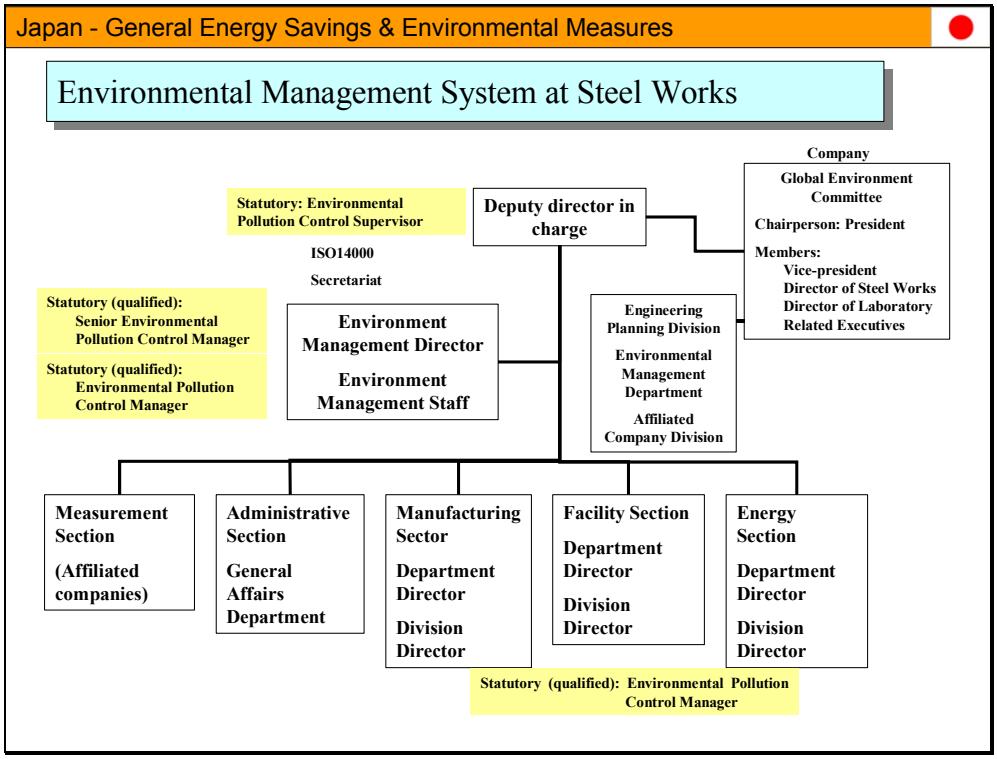


Japan – General Energy Savings & Environmental Measures

3. References



9.1 Energy Monitoring and Management Systems



9.2 Cogeneration

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Use of Unused Energy in the Vicinity Region

(Outside of Steel Works)

- Heat supply – Promoting energy savings in the community?

Steam generated by the power station is supplied to nearby sake breweries for sake production,including rice steaming,bottle washing and sterilization procedures.The heat supplied from the power station eliminates the need for each brewery to have a boiler,and thus contributes to energy savings.



Steam generator

The steam supplied for electricity generation passes through heat exchanger where indirect steam is newly produced.This steam is conveyed to each brewery through piping buried beneath the streets.

9.3 Technology for Effective Use of Slag

Japan - General Energy Savings & Environmental Measures

Technology for Effective Use of Slag

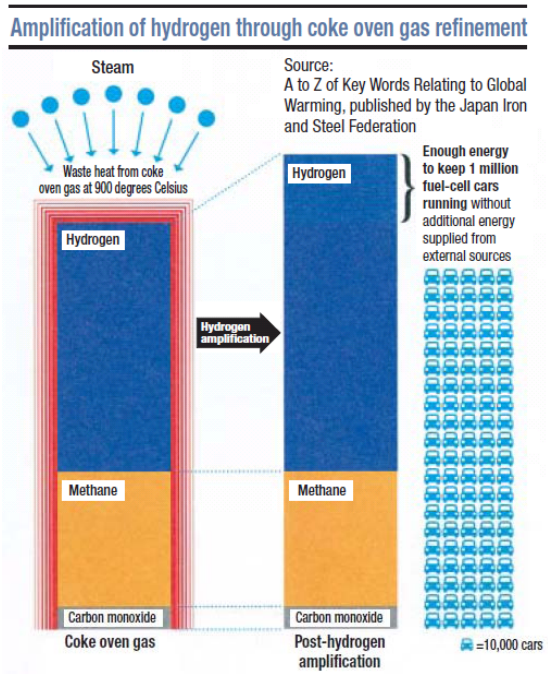
- Characteristics of concrete made form electric furnace slag and low-quality aggregate
- Development of technology for restoring ecosystem in water areas using converter slag as a purification catalyst
- Research on the mechanism for preventing dusting of smelting slag
- Development of technology for using blast-furnace slag as material for land improvement
- Detoxification and effective use of tramp elements arising from iron scrap

9.4 Hydrogen Production

Japan – General Energy Savings & Environmental Measures

Development of High-efficiency Hydrogen Production Technology

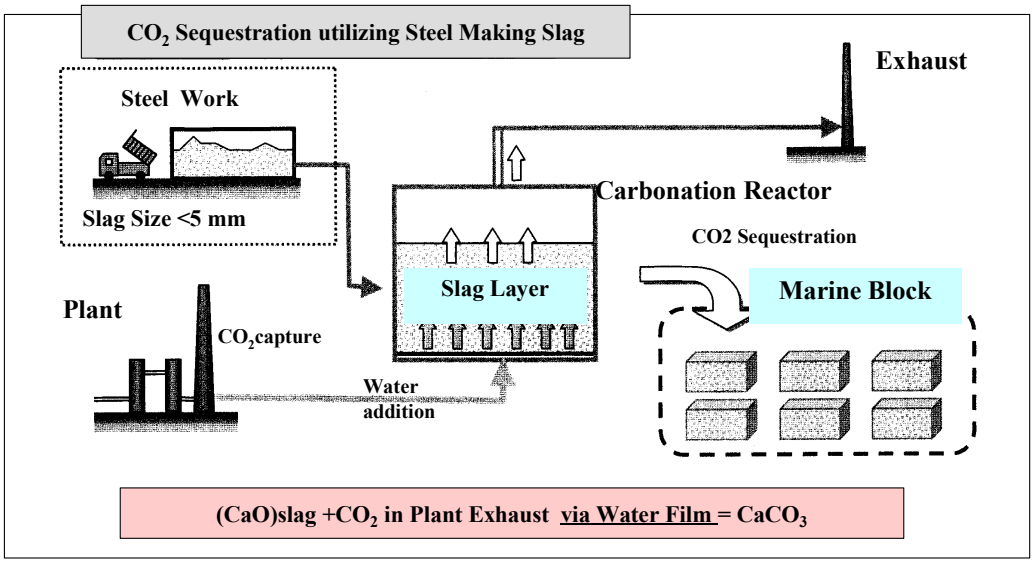
- Verification tests are currently being promoted
- The development of a separation membrane is an important element.
- Production of hydrogen by effectively utilizing 900°C COG exhaust heat without the addition of outside energy



9.5 Carbonation of Steel Slag

Japan – General Energy Savings & Environmental Measures

Reduction of CO_2 in Exhaust Gas by Carbonation of Steel Making Slag



References