INDIA
Technologies Customized List

&

Technologies One by One Sheets

2022 version Part 1: BF-BOF (v.5.0)

Recommended technologies for energy-saving, environmental protection and recycling in Indian iron and steel industry

The Japan Iron and Steel Federation

Introduction

Overview

“Technologies Customized List” is a technology reference containing energy-saving, environmental-protection and recycling technologies, developed under a collaborative scheme of “The Public and Private Collaborative Meeting between Indian and Japanese Iron and Steel Industry”. The list is aimed at identifying appropriate technologies for the Indian steel industry in order to encourage energy saving and sustainable development of Indian steel industry.

The list reflects the knowledge acquired from public and private experiences of the Japanese steel industry, which achieves the highest energy efficiency in the world, and the technology needs of Indian steel industry. In this context, contents of the list are informative for public sectors for development of policies and measures, as well as for private sectors for the plan of the technology introduction and improvement of energy management activities in steel plants.

After the publication of the Technologies Customized List version 1 (2013), version 2 (2014), version 3 (2017), and version 4 (2019), the list was employed on many occasions such as Steel Plant Diagnosis and Public and Private Collaborative Meetings and Workshops. Based on the discussion at the 8th PPC meeting on the growing importance of small and medium size steel plants, it was proposed to update Technologies Customized List to include technologies for EAF plants. Thus, Technologies Customized List version 4 (2019) was compiled as two-part series: Part-1 for BF-BOF plants, and Part-2 for EAF plants. Technologies Customized List 2022 version adds several new technologies and includes updated reference information and supplier contact.

TCL Ver.1~4

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Technologies One by One Sheets
2022 version (v.4.2) Part 2: EAF
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TCL 2022 version

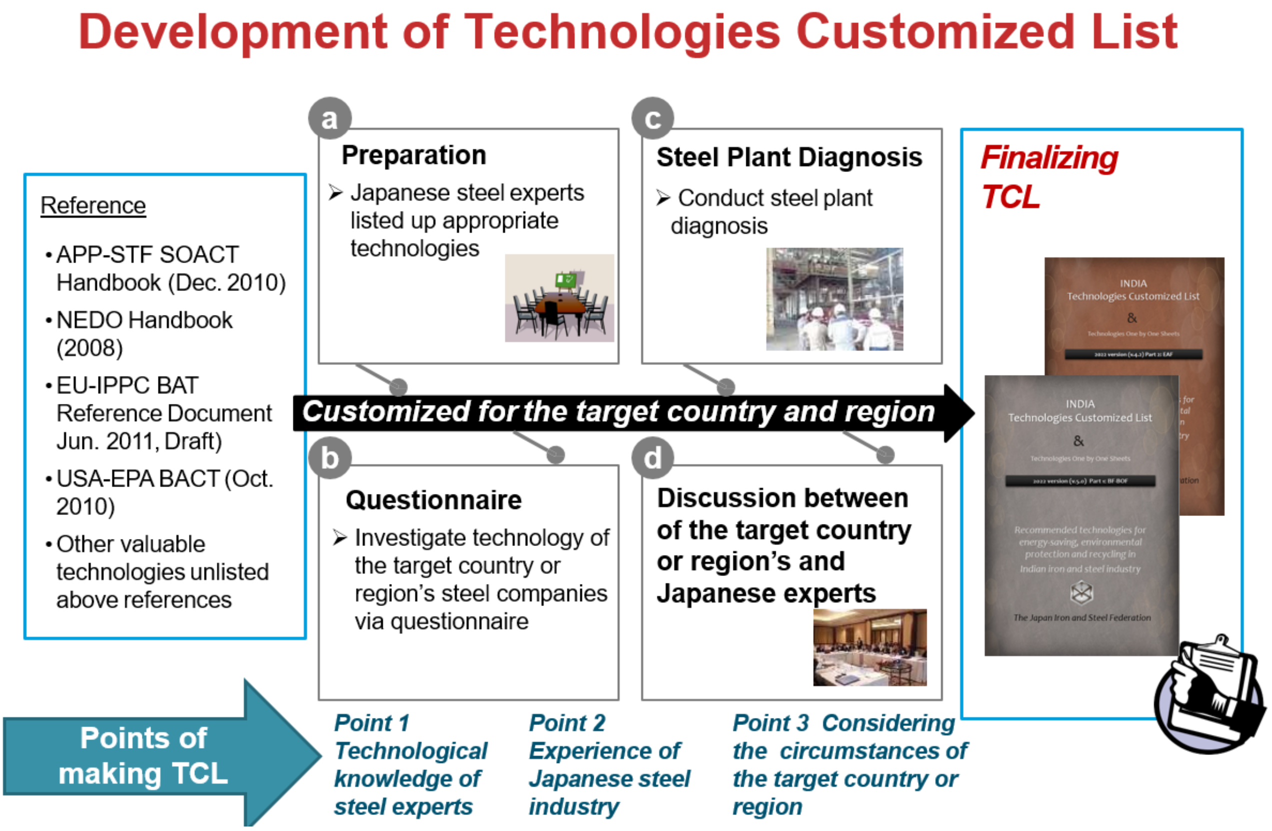
Development process of Technologies Customized List

Technologies on the Technologies Customized List are considered to contribute to energy saving and environmental protection in Indian steel industry. They were chosen from several technology references*[1] in the world, based on the following criteria.

1. **Coverage**: Technologies Customized List contains the technologies for energy saving, environmental protection and recycling in the steel plants in India. Technologies for other purposes, such as quality improvement and production increase, are not covered in Technologies Customized List.

2. **Availability**: Target technologies should be commercially available. Technologies under development in Japan, which the supplier companies are not ready to diffuse in India, are not eligible for Technologies Customized List.

3. **Experience**: Steel experts in Japan have technological knowledge and experiences.



Development of Technologies Customized List

Reference
- APP-STF SOACT Handbook (Dec. 2010)
- NEDO Handbook (2008)
- EU-IPPC BAT Reference Document Jun. 2011, Draft)
- USA-EPA BACT (Oct. 2010)
- Other valuable technologies unlisted above references

a **Preparation**
- Japanese steel experts listed up appropriate technologies

c **Steel Plant Diagnosis**
- Conduct steel plant diagnosis

Customized for the target country and region

b **Questionnaire**
- Investigate technology of the target country or region's steel companies via questionnaire

d **Discussion between of the target country or region's and Japanese experts**

Finalizing TCL

Points of making TCL

Point 1 Technological knowledge of steel experts

Point 2 Experience of Japanese steel industry

Point 3 Considering the circumstances of the target country or region

Technologies Customized List 2022 version
January, 2022

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*[1] Reference List
- The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook
- NEDO Handbook
- EU-IPCC BAT
- USA-EPA-BACT

Table of Contents

1. Energy-Saving Technologies

1-1. Technologies Customized List

Technologies Customized List of Energy Saving Technologies for Indian Steel Industry 2022 version part-1: BF-BOF (v.5.0)

No.	Title of Technology	Technical Description	Expected Effects of Introduction					Diffusion Rate of Technology in 7 Major Steel Companies, % [*1]
			Electricity Savings	Fuel Savings	CO2 Reduction	Estimation Details	Co- benefits	
			kWh/t of product	GJ/t of product	kg- CO2/t of product			
Sintering (product: sinter)								
A-1	Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat)	The device recovers the sensible heat in the hot air with temperature of 250C to 450C from a sinter cooler.	**-**	**0.25**	**23.86 (emission factor: coal)**	**-**	SOx, NOx, Dust	23
A-2	Sinter Plant Heat Recovery (Power Generation from Sinter Cooler Waste Heat)	This is a waste gas sensible heat recovery system from sinter cooler to generate electric energy.	**22.1**	**-**	**19.96**	**-**	-	8
A-3	High Efficient (COG) Burner in Ignition Furnace for Sinter Plant	The multi-slit burner can form a successive and uniform frame in the ignition furnace using coke oven gas.	**-**	**0.01**	**0.44 (emission factor: COG)**	**-**	-	53
Cokemaking (product: coke)								
A-4	Coke Dry Quenching (CDQ)	The heat recovered by inert gas from the hot coke is used to produce steam, which may be used on-site or to generate electricity.	**-**	**1.90**	**97.5 (emission factor: steam)**	assuming steam substitution	-	22
			150	**-**	**135.45**	assuming electricity substitution		
A-5	Coal Moisture Control (CMC)	Coal moisture control uses the waste heat from the coke oven gas to dry the coal used for coke making. Coal moisture is changed from 8-9% to 3-5%, which reduces fuel consumption in the coke oven.	**-**	**0.29**	**27.55 (emission factor: steam coal)**	**-**	-	2
Ironmaking (product: pig iron)								
A-6	Top Pressure Recovery Turbine (TRT)	This system generates electric power by employing blast furnace top gas to drive a turbine generator. Blast furnace gas passed through TRT is used as a fuel in iron and steel making processes.	**50**	**-**	**45.15**	**-**	-	42
A-7	Multi-Vessel Electrostatic Precipitator	This system cleans the blast furnace gas that goes into TRT power generation system through removing dust and water drops by electrostatic field.	**64.8 MWh/day**	**12.9 ton-CO2/day**	**-**	-	-	0
A-8	Pulverized Coal Injection (PCI) System	This technology is for injecting pulverized coal directly through the blast furnace tuyeres as a partial substitute for the coke used in the blast furnace.	**-**	**1.55**	**147 (emission factor: steam coal)**	assuming 125kg coal injection	-	91
A-9	Hot Stove Waste Heat Recovery	This device recovers the sensible heat of the flue gas generated in the hot stove and uses this heat in preheating fuel and combustion air for the hot stoves.	**-**	**0.08**	**7.89 (emission factor: steam coal)**	**-**	-	46
A-10	Top Combustion type Hot Stove with Metallic Burners	Coming Soon						
Steelmaking (product: steel)								
A-11	Converter Gas Recovery Device	This device recovers and uses the high temperature waste gas generated during blowing in the converter (basic oxygen furnace).	**-**	**0.84**	**79.8 (emission factor: steam coal)**	**-**	-	88 [*2]
A-12	Low NOx regenerative burner system for ladle preheating	- Regenerating burner use - High Energy Saving (about 40 %) - Automatic control - FDI Combustion	**-**	**0.20**	**12.62**	**-**	**Contribute to better atmosphere around at workfloor**	-

No.	Title of Technology	Technical Description	Expected Effects of Introduction					Diffusion Rate of Technology in 7 Major Steel Companies, % [*1]
			Electricity Savings	Fuel Savings	CO2 Reduction	Estimation Details	Co- benefits	
			kWh/t of product	GJ/t of product	kg- CO2/t of product			
A-13	Converter Gas Sensible Heat Recovery Device	This device recovers and uses the high temperature waste gas generated during blowing in the converter (basic oxygen furnace). This device burns the converter waste gas to transform latent heat to sensible heat and recovers the sensible heat.	-	**0.13**	**11.97 (emission factor: steam coal)**	-	-	**0**
Recycling and Waste Reduction								
A-14	Rotary Hearth Furnace (RHF) Dust Recycling System	In the RHF, the dust and sludge along with iron oxide and carbon are agglomerated into shaped articles and iron oxide is reduced into DRI, which reduces coke consumption in the blast furnace.	-	**0.21**	**22.5 (emission factor: coke)**	-	Dust	No data
Processing (product: steel products)								
A-15	Process control for reheating furnace	- Setting furnace temperature by targeted billet temperature curve - Precise air ratio control and O2 analysis in exhaust gas	-	0.05	3.16	-	-	-
A-16	Regenerative Burner Total System for reheating furnace	While one of the burners is burning, the other burner will work as an exhaust outlet. The combustion air will be preheated to a superhigh temperature.	-	**0.19**	**10.66 (emission factor: natural gas)**	Fuel saving and CO2 reduction are average values	NOx	31
A-17	High temperature recuperator for reheating furnace	- Heat transfer area is expanded - Special material tube is used instead of stainless	-	**0.10**	**6.31**	-	-	-
A-18	Fiber block for insulation of reheating furnace	- Low thermal conductivity - High temperature change response (low thermal-inertia)	-	**0.04**	**2.46**	-	-	-
A-19	Induction type billet heater for direct rolling	Compensate temperature drop of billets transferred from CC to rolling mill (from 950 degC to 1050 degC). Advantages : - Automatic control - Less exhaust gas (without reheating furnace)	**-40**	**1.45**	**127.70**	-	-	-
A-20	Oxygen enrichment for combustion air	Silicon-carbide parts are inserted into the radiant tube to promote heat transfer from hot gas to the tube, which improve thermal efficiency of the furnace. Production of the target plant is assumed as 594,000 ton/y (CGL) with natural gas use.	**-23.6**	**0.26**	**37.76**	-	-	-
A-21	Highly efficient combustion system for radiant tube burner	Silicon-carbide parts are inserted into the radiant tube to promote heat transfer from hot gas to the tube, which improve thermal efficiency of the furnace. Production of the target plant is assumed as 594,000 ton/y (CGL) with natural gas use.	-	**0.0896**	**5.03 (emission factor: natural gas)**	-	-	-

No.	Title of Technology	Technical Description	Expected Effects of Introduction					Diffusion Rate of Technology in 7 Major Steel Companies, % [*1]
			Electricity Savings	Fuel Savings	CO2 Reduction	Estimation Details	Co- benefits	
			kWh/t of product	GJ/t of product	kg- CO2/t of product			
General Energy Saving & Environmental Measures								
A-22	Inverter (VVVF; Variable Voltage Valuable Frequency) Drive for Motors	An inverter is a variable speed device controlling frequency and voltage to allow precise control of rotation of a motor.	**13%**	**-**	**-**	**-**	-	-
A-23	Energy Monitoring and Management Systems	This measure includes site energy management systems for optimal energy recovery and distribution between various processes and plants	**-**	**0.12**	**11.40 (emission factor: steam coal)**	**-**	-	89
A-24	Cogeneration (include Gas Turbine Combined Cycle (GTCC))	This equipment is a high efficiency combined generator set using the by-product gas produced during iron and steel making process.	Coming Soon					
A-25	Management of Compressed Air Delivery Pressure Optimization	Energy saving in compressors requires consideration of the points like (1) selection of the appropriate capacity, (2) reduction in delivery pressure.	**285 MWh/y**	**-**	**-**	**-**	-	No data
A-26	Power Recovery by Installation of Steam Turbine in Steam Pressure Reducing Line	This technology reduces refrigerator power consumption by installing a steam turning in place of the steam pressure reducing valve and driving the refrigerator with the power recovered by the steam turbine.	**4,308 MWh/y**	**-**	**-**	**-**	-	No data

*1) Diffusion rate is calculated from the answer for questionnaire of 7 major steel companies in 2016.
*2) Diffusion rate of OG boiler is Zero.

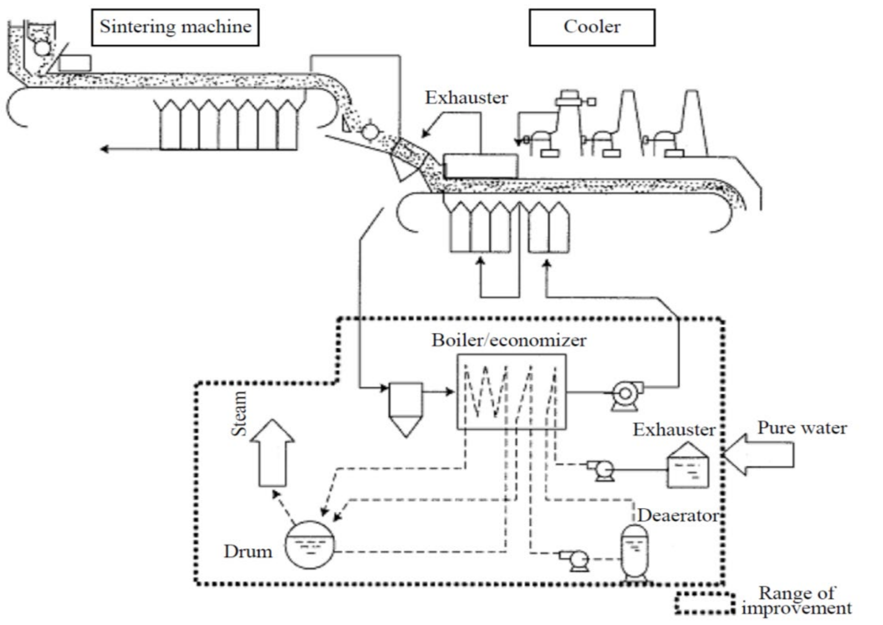
1. Energy-Saving Technologies

1-2. Technologies One by One Sheet

A-1

Sintering

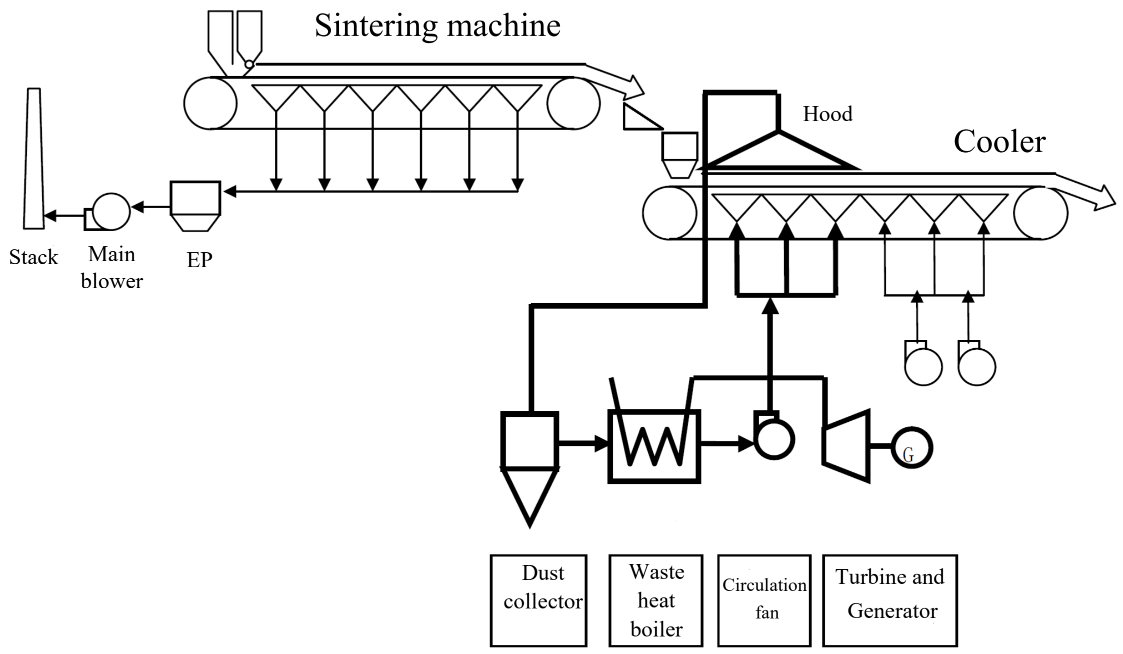
Sinter Plant Heat Recovery
(Steam Recovery from Sinter Cooler Waste Heat)

Item		Content
1. Process Flow		 Steam recovery system from sintering machine
2. Technology Definition/Specification		This device recovers the sensible heat in the hot air with temperature of 250 C to 450 C from a sinter cooler. It comprises mainly; a) boiler/economizer, b) pure water feed device, c) deaerator d) steam drum, etc. After heat exchange with sintered ores of 500 C to 700 C in the cooler, the exhaust gas is introduced to the boiler/economizer to generate steam and is recycled to the cooler. Unit recovery of waste heat is on the order of 60,000 kcal/t-sinter The sensitive heat can be recovered by one or more of the following ways: ・steam generation in a waste heat boiler ・hot water generation for local heating ・preheating combustion air in the ignition furnace ・power generation
3. Investment Cost & Operating Life		Equipment cost : approx.￥3,000 million (annual sinter production : 1 mil. ton/y)【177 Crore】 Construction cost: approx. ￥500 million【30 Crore】
4. Effect of Technology Introduction	・Reduction of CO2 Emission	23.86kg-CO2/t-sinter
	・Fuel Savings	0.251GJ/t-sinter [NEDO]：60,000 kcal/t-sinter/ 1,000,000 * 4.186
5. Direct Effect (Annual Operating Cost)	・Economic Effect （payback time）	payback time [NEDO] : Equipment only : approx. 22.1 years【11.6 years】 : Including construction cost : approx. 25.8 years【13.5 years】 Annual steam recovery : 60,000 * 10^6 kcal/y Reduction in crude oil equivalent : 7,500 t-crude oil/y Economic effect : ￥135.8 mil./y (=60,000 * (1.81/0.8) / 1,000)【153 Crore】
	・Productivity Improvement	Not announced
	・Maintenance Cost Reduction	Not announced
6. Indirect Effect （Co-benefits）	・Product Quality Improvement	Not announced
	・SOx, Dust Decrease	Not announced
7. Diffusion Rate of Technology in Japan		widely spread and mostly applied
8. Japanese Main Supplier		JP Steel Plantech Co.
9. Technologies Reference:		Nippon Kokan Technical Report, 1980, No.84, 25
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】. * Payback time was defined as (Investment cost / Economical merit) in this project. * annual sinter production : 1 mil. ton/y * CO2 emission factor of coal : 0.095 * unit cost of C heavy oil : ￥1.81/ 1,000 kcal [NEDO] overall boiler efficiency : 0.8 Economic effect : 60,000 * 1.81 /0.80 = ￥136 mil./y

A-2

Sintering

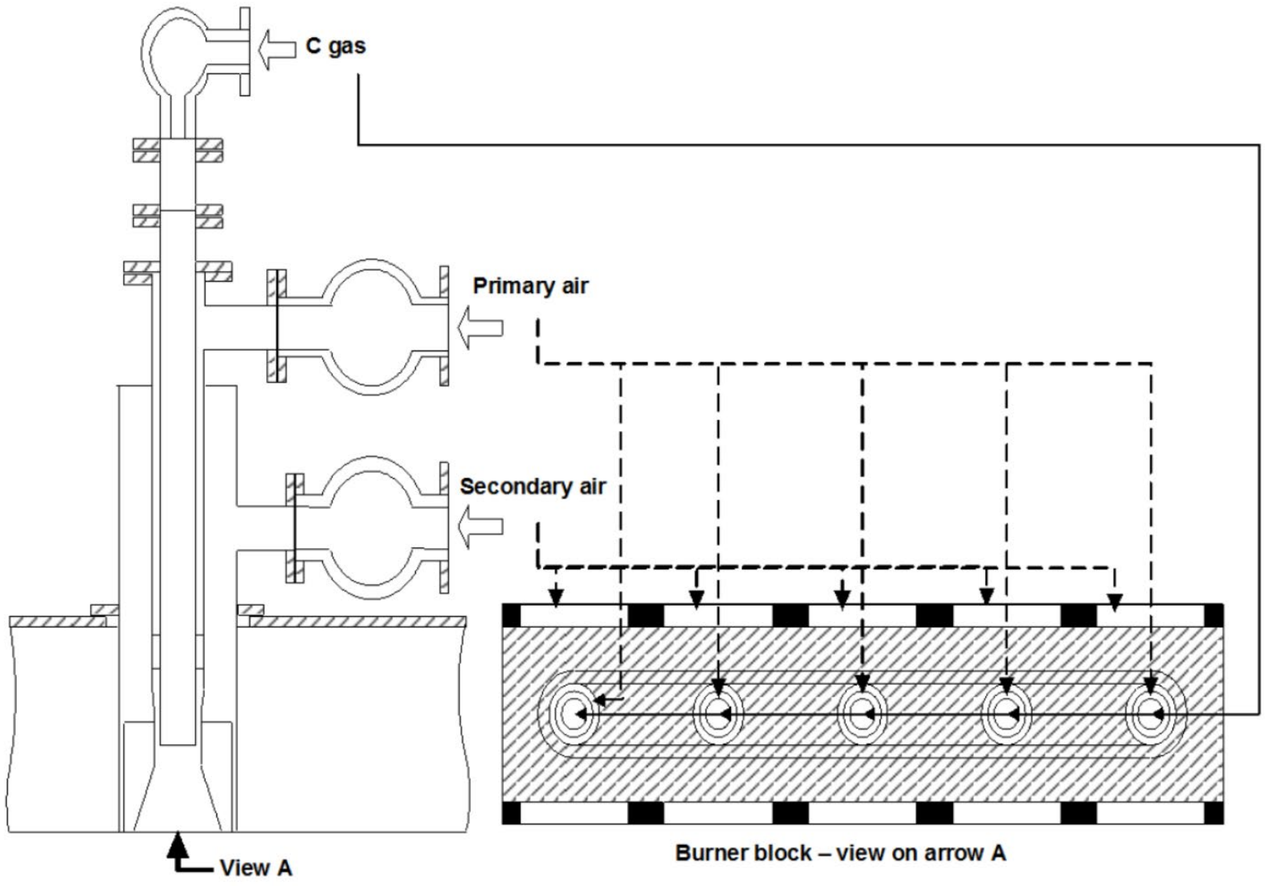
Sinter Plant Heat Recovery
(Power Generation from Sinter Cooler Waste Heat)

Item		Content
1. Process Flow		 Sinter cooler waste heat recovery system
2. Technology Definition/Specification		This is a waste gas sensible heat recovery system from sinter cooler to generate electric energy. The system is composed of dust collector, waste heat recovery boiler as steam, circulation fan and power generator by steam turbine. The figures listed below are obtained from a system configuration of two identical sintering machines, coolers each equipped with waste heat recovery boiler and one unit of electric power generator, to which the steam from two boilers is led.
3. Investment Cost & Operating Life		approx.￥5 billion at 5.9Mt/y【295 Crore】
4. Effect of Technology Introduction	･Reduction of CO2 Emission	19.96 kg-CO2/t-sinter
	･Fuel Savings	0.253GJ/t-sinter = 17,400kWh/h * 2,717kcal/kWh /1,000,000 /(393 t-Sr/h * 2) * 4.186 GJ/Gcal
	･Electricity Savings	22.1 kWh/t-sinter = 17,400 kWh/(393t-Sr/h * 2)
5. Direct Effect (Annual Operating Cost)	･Economic Effect （payback time）	2.9 years【5.5 years】 (Reduction in crude oil equivalent：32,500 Toe/y = 17,400 kWh/h * 24h/D * 365 D/Y * 0.85 * 0.95 * 2,646 kcal/kWh /10,000 kcal)
	･Productivity Improvement	Not announced
	･Maintenance Cost Reduction	Not announced
6. Indirect Effect （Co-benefits）	･Product Quality Improvement	Not announced
	･SOx, Dust Decrease	Not announced
7. Diffusion Rate of Technology in Japan		well known and familiarized
8. Japanese Main Supplier		JP Steel Plantech Co.
9. Technologies Reference:		2006 NEDO project report, No.06002211-0
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】. * Payback time is defined as (Investment cost / Economical merit) in this project. 1. Sinter operation conditions - production 393 t/h × 2 units - sinter qty in cooler 540 t/h × 2 units - sinter surface temperature at cooler exit ＜125 C - sinter layer height in cooler 1,000 mm - circulating waste gas volume 650,000 Mm3/h × 2 units 2. Electricity recovered 17,400 kWh / 2 units or 129,560,400 kWh/y (equivalent to 310 days) 3. Reduction in crude oil equivalent 32,500 Toe/y 4. Electricity savings ￥1.7 billion/y (Electricity price : 14 ￥/kWh = 0.123 US$/kWh * 113 ￥/US$) 5. Payback time 2.9 years (Investment cost /(Ele. savings running cost)

A-3

Sintering

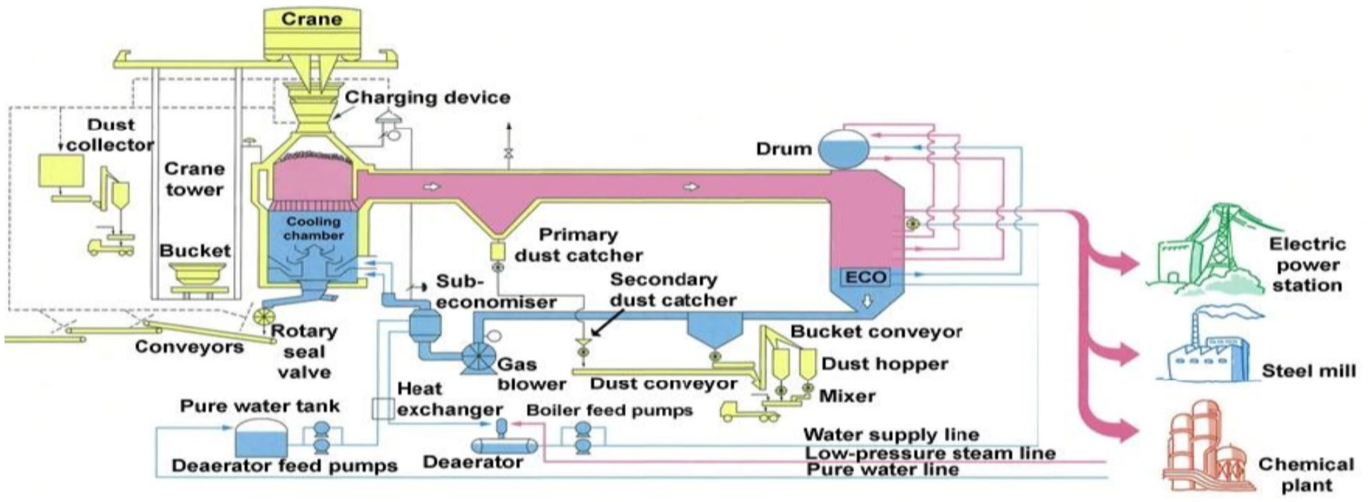
High Efficient (COG) Burner in Ignition Furnace for Sinter Plant

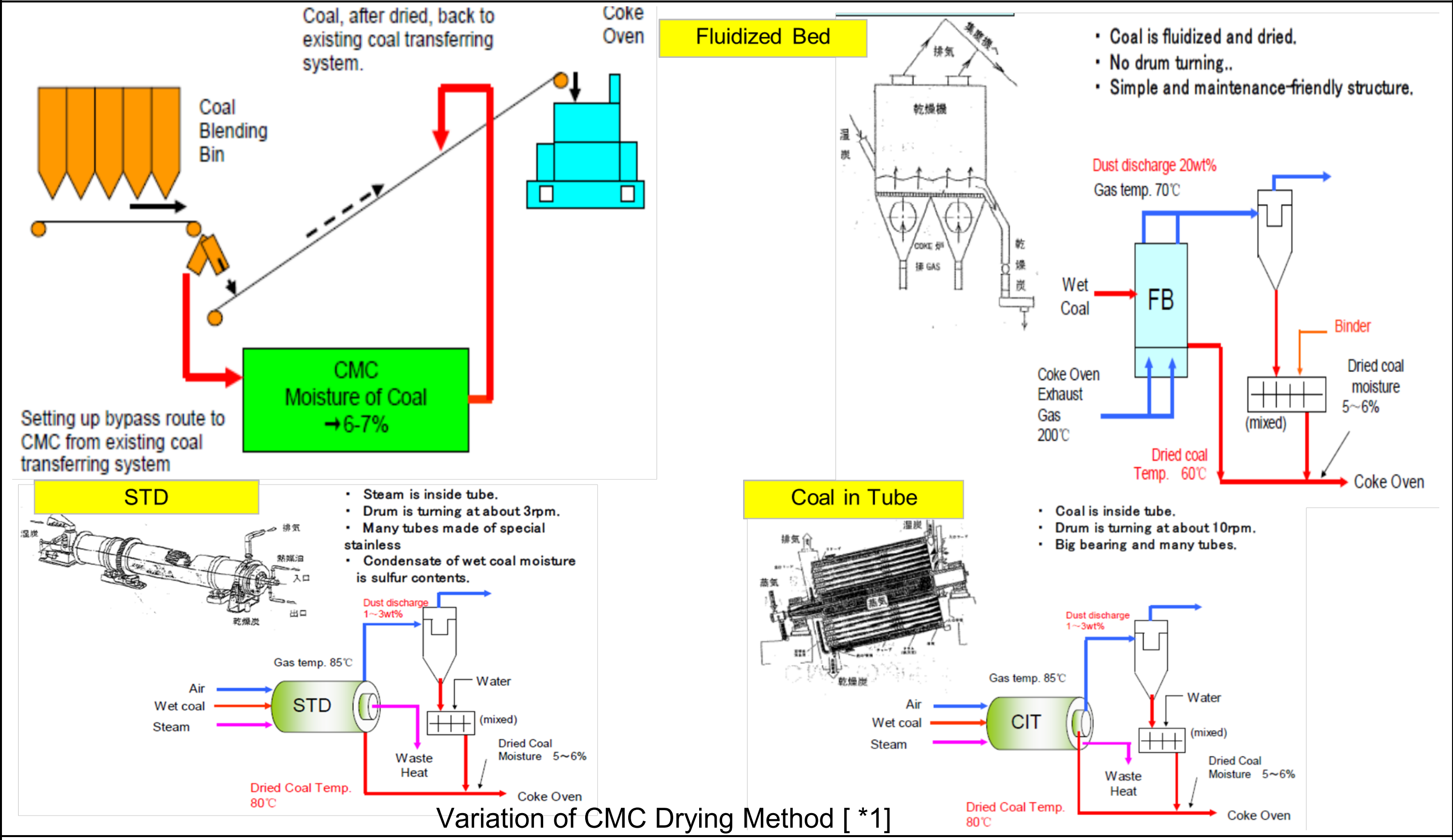
Item		Content
1. Process Flow		 Outline of multi-slit burner
2. Technology Definition/Specification		The multi-slit burner is designed to form a successive and uniform frame along a pallet width direction in the ignition furnace. It consists of fuel exhaust nozzles and a slit-like burner tile containing these nozzles. The fuel, coke oven gas, supplied from the fuel exhaust nozzles reacts with the primary air inside the burner tile, then with the secondary air supplied to the periphery area of the frame. By lining up the burner block, the frame can cover the whole surface of the bed along the width direction. By controlling the primary/secondary air ratio, the length of the frame can be controlled to minimize the energy consumption for ignition.
3. Investment Cost & Operating Life		No data
4. Effect of Technology Introduction	･Reduction of CO2 Emission	0.44kg-CO2/t-sinter
	･Fuel Savings	0.010GJ/t-sinter : 2.5Mcal/t-sinter/1,000 * 4.186 [NEDO] 30% decrease in heat input for ignition [SOACT]
5. Direct Effect （Annual Operating Cost）	･Economic Effect（payback time）	Not announced
	･Productivity Improvement	Not announced
	･Maintenance Cost Reduction	Not announced
6. Indirect Effect （Co-benefits）	･Product Quality Improvement	Not announced
	･SOx, Dust Decrease	Not announced
7. Diffusion Rate of Technology in Japan		well known and familiarized
8. Japanese Main Supplier		JP Steel Plantech Co.
9. Technologies Reference:		Refer to http://asiapacificpartnership.org/japanese/soact2nd.aspx and "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》 (NEDO, 2008)"
10. Preconditions		* Payback time is defined as (Investment cost / Economical merit) in this project.

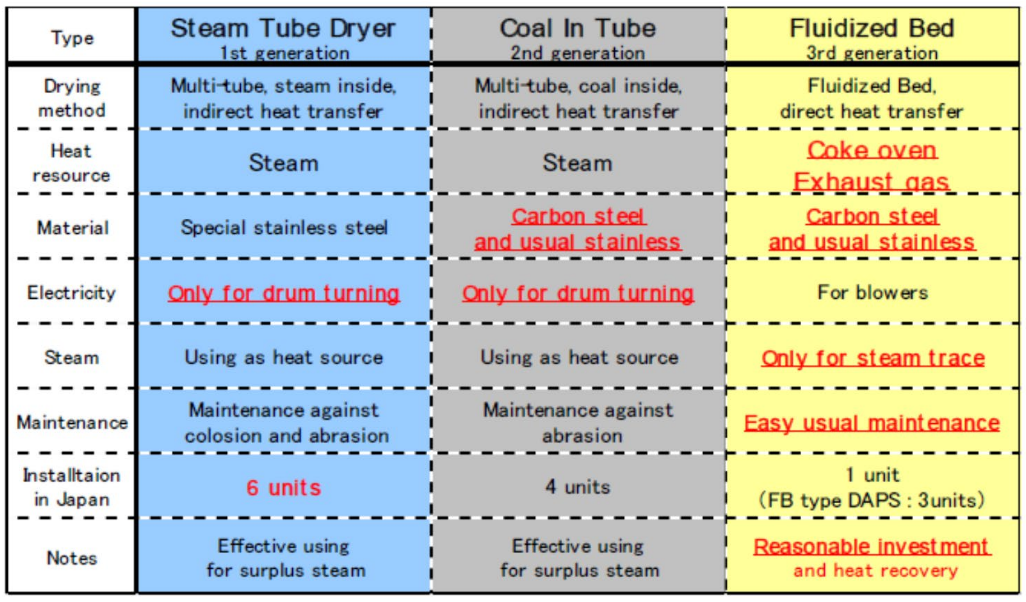
A-4

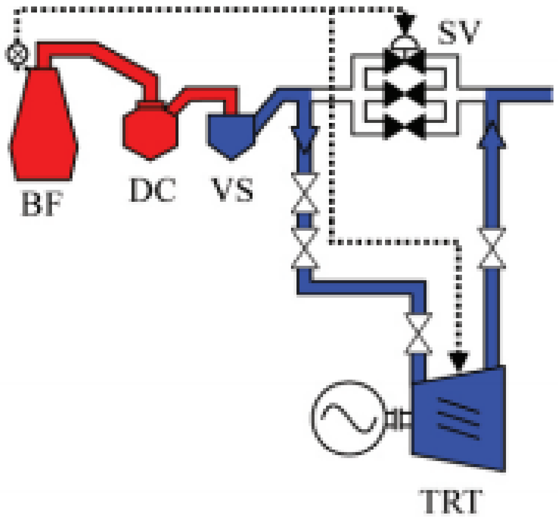
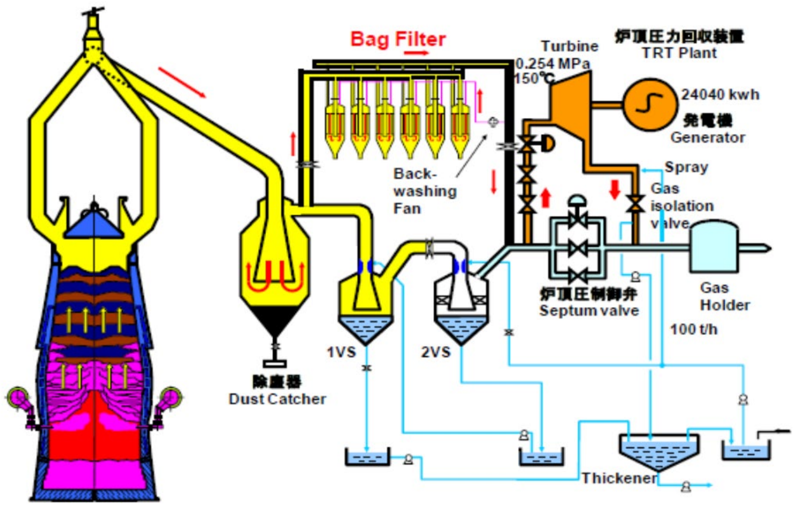
Cokemaking

Coke Dry Quenching

Item		Content
1. Process Flow		
2. Technology Definition/Specification		The heat recovered by inert gas is used to produce steam, which may be used on-site or to generate electricity. 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 1) cooling chamber 2) dust collecting bunker 3) waste heat boiler 4) dust cyclones 5) mill fan 6) blowing device (to introduce the cold air form the bottom) 7) circulating ducts 8) Capacity ;The nominal capacity of a typical CDQ plant is less than 100 t/h/chamber.(EU-BAT)[*1] 260t/h(China/ Shougang Jingtang/NSC-ENG) [*3]
3. Investment Cost & Operating Life		New plant costs are estimated to be $50/t coke, based on the construction costs of a recently built plant in Germany.[SOACT] Equipment cost: ￥3,000 million (approx.)【177 Crore】; construction cost: ￥500 million (approx.)【30 Crore】[NEDO] Operating Life : increased life by regular maintenance
4. Effect of Technology Introduction	• Reduction of CO2 Emission	97.5 kg-CO2/t-coke (assuming fuel substitution) 135.45 kg-CO2/t-coke (assuming electricity substitution)
	• Fuel Savings	1.9 GJ/t-coke : heat usage (500 kg-steam/t-coke) = 0.5 t-steam/t-coke * 3.8 GJ/t-steam (Energy conversion factor of water vapor : 3.8 GJ/t-steam)
	• Electricity Savings	150kWh/t-coke : electric usage(300KWh/t-steam)(500kg-steam/t-coke)[NEDO]
5. Direct Effect (Annual Operating Cost)	• Economic Effect (payback time)	payback time [NEDO] : Equipment only : approx. 3.1 years : Including construction cost : approx. 3.6 years (annual coke production : 450000 t, electricity price : 17.99 ￥/kWh)【4.7years】 4.4 years [EU BAT](Payback is rather sensitive to electricity prices and can vary within the EU-27 between 3 and 8 years. In addition, taking into account some European energy saving schemes such as 'Tradable Certificates for Energy savings', which have been implemented in some European countries,the above payback is expected to be much shorter)[*3]
	• Productivity Improvement	Not announced
	• Maintenance Cost Reduction	According to an actual operational record in Japan, Maintenance is usually carried out during the periodic maintenance of the coke ovens. Only a small amount of additional maintenance time is required.[EU][*1]
6. Indirect Effect (Co-benefits)	• Product Quality Improvement	Better quality coke produced, improved strength of coke by 4%[SOACT] Nippon Steel's performance record shows that the use of coke manufactured by dry quenching reduces the amount of coke consumption in the blast furnace by 0.24 MMBtu/ton molten iron./EPA [*4]
	• SOx, Dust Decrease	During final collecting by bag filters, emission factors of dust of less than 3 g/t coke are achievable, corresponding to less than 20 mg/Nm3. SO2 emissions are at a level of 200 mg/Nm3. Emissions to surface water are close to zero. Collected coke dust is supplied as fuel to the sinter plant.[SOACT] The handling of dry quenched coke can cause more dust emissions than the handling of wet quenched coke.The electrical power consumption of fans, the operation of various dedusting devices, etc. is not negligible. However, net energy output will be rather positive, due to the recovery of waste heat which is usually transferred into the electrical power.[EU][*1]
	• Water-saving	Increased water efficiency[SOACT]
7. Proficiency Level of Technology in Japan		widely spread and mostly applied
8. Japanese Main Supplier		*JP Steel Plantech Co. * Nippon Steel Engineering Co., Ltd * Paul Wurth IHI Co., Ltd.
9. Technologies Reference:		*1 : EU BAT5.3.14 *2 : Reference : 290 / NSC-ENG Personal Communication, 2008. *3 :"Establishment of coke dry quenching technology with a maximum coke throughput of 200T/H". KATAOKA S, et.,al : Proc 6th Int Iron Steel Congr 1990 Vol 2 Page.337-344 (1990) *4 EPA "AVAILABLE AND EMERGING TECHNOLOGIES FOR REDUCING GHG EMISSIONS FROM THE IRON & STEEL INDUSTRY": IV.A2.p.21
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】. * Payback time is defined as (Investment cost / Economical merit) in this project. * Refer to http://asiapacificpartnership.org/japanese/soact2nd.aspx and "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)"

<table>
<tr><td colspan="2"><h1>A-5</h1></td><td><h1>Cokemaking</h1><h2>Coal Moisture Control</h2></td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow</td><td>

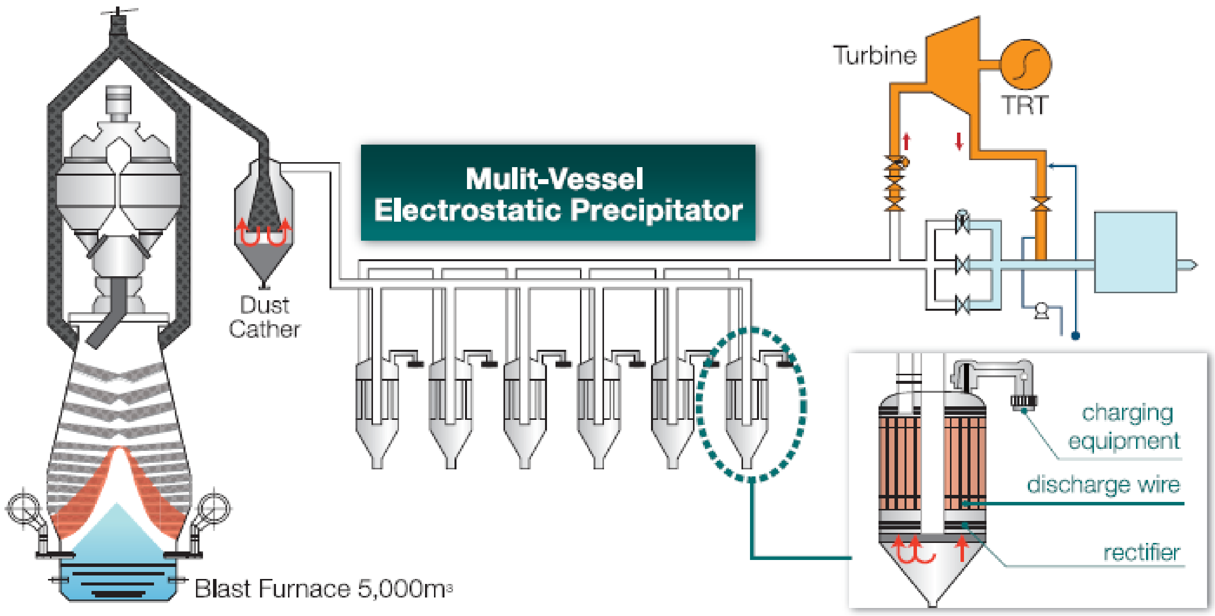
・Coal is fluidized and dried.
・No drum turning..
・Simple and maintenance-friendly structure.
・Steam is inside tube.
・Drum is turning at about 3rpm.
・Many tubes made of special stainless
・Condensate of wet coal moisture is sulfur contents.
・Coal is inside tube.
・Drum is turning at about 10rpm.
・Big bearing and many tubes.
Variation of CMC Drying Method [*1]</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>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. Drying further reduces the coal moisture content to a constant 3-5%, 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.[SOACT]Generally, low-pressure steam is used as the humidity control heat source.[NEDO]
<u>Comparison of CMC Drying Method</u>
<table>
<tr><th>Type</th><th>Steam Tube Dryer
1st generation</th><th>Coal In Tube
2nd generation</th><th>Fluidized Bed
3rd generation</th></tr>
<tr><td>Drying method</td><td>Multi-tube, steam inside, indirect heat transfer</td><td>Multi-tube, coal inside, indirect heat transfer</td><td>Fluidized Bed, direct heat transfer</td></tr>
<tr><td>Heat resource</td><td>Steam</td><td>Steam</td><td><u>Coke oven Exhaust gas</u></td></tr>
<tr><td>Material</td><td>Special stainless steel</td><td><u>Carbon steel and usual stainless</u></td><td><u>Carbon steel and usual stainless</u></td></tr>
<tr><td>Electricity</td><td><u>Only for drum turning</u></td><td><u>Only for drum turning</u></td><td>For blowers</td></tr>
<tr><td>Steam</td><td>Using as heat source</td><td>Using as heat source</td><td><u>Only for steam trace</u></td></tr>
<tr><td>Maintenance</td><td>Maintenance against colosion and abrasion</td><td>Maintenance against abrasion</td><td><u>Easy usual maintenance</u></td></tr>
<tr><td>Installtaion in Japan</td><td>6 units</td><td>4 units</td><td>1 unit
（FB type DAPS : 3units）</td></tr>
<tr><td>Notes</td><td>Effective using for surplus steam</td><td>Effective using for surplus steam</td><td><u>Reasonable investment</u> and heat recovery</td></tr>
</table></td></tr>
<tr><td colspan="2">3. Investment Cost
& Operating Life</td><td>Coal humidity control cost in Japan: Approx. $21.9/t-steel[SOACT,NEDO]
Equipment cost: ￥2,000 million【118 Crore】; construction cost: ￥500 million【30 Crore】/ 450,000t-coke/y[NEDO]
Operating Life : increased life by regular maintenance</td></tr>
<tr><td rowspan="3">4. Effect of Technology Introduction</td><td>・Reduction of CO2 Emission</td><td>27.55 kg-CO2-/t-coke</td></tr>
<tr><td>・Fuel Savings</td><td>Fuel savings of approximately 0.29 GJ/t-coke[SOACT]</td></tr>
<tr><td>・Electricity Savings</td><td>Not announced</td></tr>
<tr><td rowspan="3">5. Direct Effect（Annual Operating Cost）</td><td>・Economic Effect（payback time）</td><td>Cheaper lean coal blend ratio increase[*1]
payback time: Not announced</td></tr>
<tr><td>・Productivity Improvement</td><td>Coke production increase (about 10%)/Shorter cooking times[SOACT,NEDO]</td></tr>
<tr><td>・Maintenance Cost Reduction</td><td>Careful attention needed to corrosion znd abrasion for STD and CIT</td></tr>
<tr><td rowspan="3">6. Indirect Effect（Co-benefits）</td><td>・Product Quality Improvement</td><td>Coke quality improvement (about 1.7%)[SOACT,NEDO]</td></tr>
<tr><td>・SOx, Dust Decrease</td><td>Not announced</td></tr>
<tr><td>・Water-saving</td><td>Decrease in water pollution (ammonia reduction)[SOACT]</td></tr>
<tr><td colspan="2">7. Proficiency Level of Technology in Japan</td><td>well known and familiarized</td></tr>
<tr><td colspan="2">8. Japanese Main Supplier</td><td>* Nippon Steel Engineering Co., Ltd * Tsukishima Kikai CO., LTD.</td></tr>
<tr><td colspan="2">9. Technologies Reference:</td><td>*1 : SOACT Appendix2a</td></tr>
<tr><td colspan="2">10. Preconditions</td><td>* Important values were revised with referring to various values in "1-4. Used values and applied preconditions."
Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】.
* Refer to http://asiapacificpartnership.org/japanese/soact2nd.aspx and "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)"</td></tr>
</table>

A-6		Ironmaking Top Pressure Recovery Turbine
Item		Content
1. Process Flow		Wet Type Dust Cleaner  Dry Type Dust Cleaner  Assuming pig iron production of 1 million t/y, the blast furnace capacity is 1,500m3 (daily production scale: 3,000t) and B-gas generation is 212,500m3/h. The possible generating capacity with the gas volume is approximately 7,000kW (dry type). [NEDO]
2. Technology Definition/Specification		This system generates electric power by employing blast furnace top gas to drive a turbinegenerator. After the blast furnace gas is used in power generation, it is used as a fuel in iron and steel manufacturing processes. Blast furnace gas (BFG) has a pressure of 0.2-0.236MPa (2-2.41 kg/cm2) and temperature of approximately 200°C at the furnace top. This technology is a method of generating power by employing this heat and pressure to drive a turbinegenerator. The system comprises dust collecting equipment, a gas turbine, and a generator. Generating methods are classified as (1) wet or (2) dry depending on the B-gas purification method. Dust is removed by Venturi scrubbers in the wet method and by a dry-type dust collector in the dry method. When dust is treated by the dry method, the gas temperature drop is small in comparison with the wet method, and as a result, generated output is at maximum 1.6 times greater than with the wet method[NEDO]
3. Investment Cost & Operating Life		Equipment cost : 7,000kW Generator ; ￥1,400million (approx.)【83 Crore】, Construction cost : ￥400million (approx.)【24 Crore】[NEDO] Operating Life : increased life by regular maintenance
4. Effect of Technology Introduction	･Reduction of CO2 Emission	45.15 kg-CO2/t-PI
	･Fuel Savings	-
	･Electricity Savings	50 kWh/t-PI (= (40+60)/2 kWh/t-PI) [SOACT]
5. Direct Effect (Annual Operating Cost)	･Economic Effect（payback time）	More expensive than wet type, $28/t hot metal. NEDO from Japan gives 1.8 years for the payback period of VS-ESCS (Venturi Scrubber- Electrostatic Space Clear Super) (including the construction costs)[SOACT] payback time [NEDO] : Equipment only : approx. 1.4 years : Including construction cost : approx. 1.8 years (=1.8billion/(7000*24*330*17.99))【3.6 years】
	･Productivity Improvement	Not announced
	･Maintenance Cost Reduction	Excellent operational reliability, abrasion resistant[SOACT]
6. Indirect Effect （Co-benefits）	･Product Quality Improvement	Not announced
	･SOx, Dust Decrease	Not announced
	･Water-saving	Lower water consumption compared with wet type[SOACT]
7. Proficiency Level of Technology in Japan		widely spread and mostly applied
8. Japanese Main Supplier		* Mitsui E&S Machinery Co., Ltd. * Nippon Steel Engineering Co., Ltd
9. Technologies Reference:		Refer to "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)"
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】. * Payback time is defined as (Investment cost / Economical merit) in this project.

A-7

Ironmaking

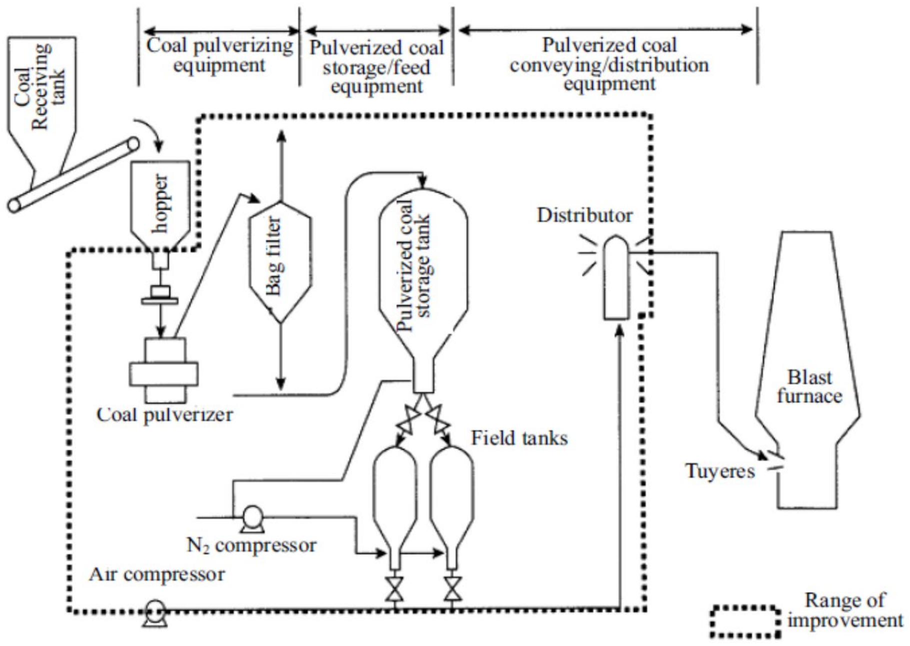
Multi-Vessel Electrostatic Precipitator

Item		Content
1. Process Flow		
2. Technology Definition/Specification		Multi-vessel electrostatic precipitator (MVEP), instead of the existing 2-stage venturi scrubber, is arranged in the system, and dust and water drops are removed by electric energy in MVEP located in the gas turnover/rising section in each vessel, which generates clean gas. Since the temperature drop and pressure loss is reduced as compared to 2-stage venturi scrubber, TRT power generation is increased by 20~30%, with realizing the dust content at the outlet of the system of 5 mg/Nm3 or lower. And, since there is no temperature limitations as compared to bag filter, this system has excellent durability at high temperature gas inlet by operation fluctuations.
3. Investment Cost & Operating Life		Investment Cost : Depending on a project case Operating Life : Equivalent to twice time blast furnace life
4. Effect of Technology Introduction	･Reduction of CO2 Emission	8.36 kg-CO2/ton-pig iron
	･Electricity Savings	9.26 kWh/ton-pig iron or 64.8 MWh /day saving, Improvement of Electricity generation is about 21% (15.8 MW at MVEP by TRT / 13.1 MW at Wet GCP by TRT).
5. Direct Effect (Annual Operating Cost)	･Economic Effect（payback time）	TRT power generation is increased by 20~30% than Wet GCP
	･Monetary equivalent of energy savings	(15.8 [MW]-13.1 [MW])*24[hr./day]*350[work-day/year]*5000[Rs./MWh ≒ 11.3 [Cr./year]
	･Maintenance Cost Reduction	Equivalent with Wet GCP (No need to replace filter cloth required with dry bag filter)
6. Indirect Effect (Co-benefits)	･Product Quality Improvement	No water consumption at MVEP
7. Diffusion Rate of Technology in Japan		One pilot plant in Japan
8. Japanese Main Supplier		Nippon Steel Engineering Co., Ltd.
9. Technologies Reference:		NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD. TECHNICAL REVIEW vol.10 (Published: May.2019)
10. Preconditions		Calculations are based on a 3000 m3 class blast furnace producing 7000 ton of pig iron per day, and the CO2 reduction amount is calculated using CO2 emission factor for grid electricity, 0.903 t-CO2/MWh (average of combined margin from CDM projects, IGES website, 2018). Both are trial values, which are not guaranteed.

A-8

Ironmaking

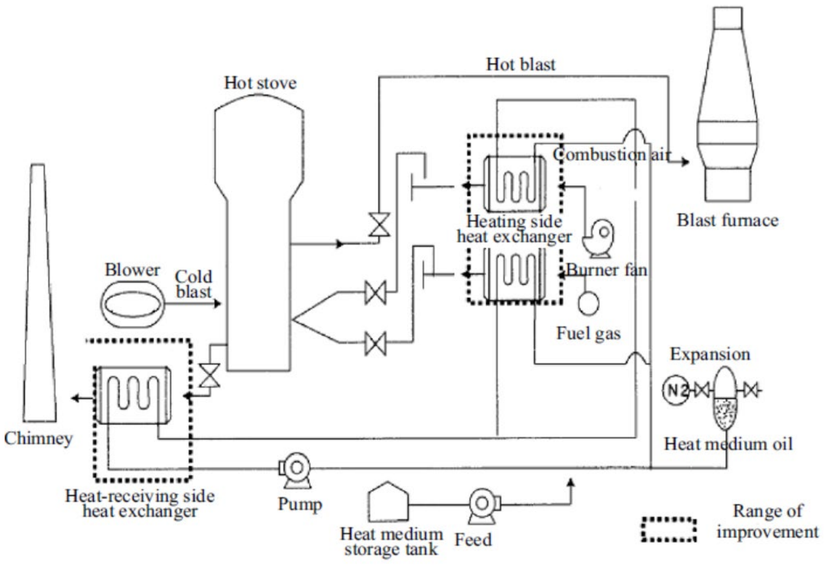
Pulverized Coal Injection (PCI) System

Item		Content
1. Process Flow		 System diagram of PCI equipment [NEDO]
2. Technology Definition/Specification		This system comprises a technology and equipment for injecting pulverized coal directly through the blast furnace tuyeres as a partial substitute for the coke used in the blast furnace. Because pulverized coal is injected directly, the corresponding amount of coke is unnecessary, making it possible to reduce energy consumption for coke making (coke dry distillation energy). This equipment comprises (1) coal receiving equipment, (2) pulverizing/drying equipment, (3) pulverized coal injection equipment and the instrumentation system. Noncoking coal is used as a partial substitute for coke (i.e., for coking coal). This coal is pulverized to a size of approximately 74μm, classified using a bag filter, and conveyed to the pulverized coal storage silo. It is then supplied at the timing of injection in accordance with the injection rate. The injection tank is pressurized with a compressor, and the pulverized coal is conveyed to the blast furnace tuyeres (charging holes) and injected into the blast furnace using this pressure. However, the type of coal used and the size of the pulverized coal will differ depending on the injection equipment and the blast furnace.
3. Investment Cost & Operating Life		Equipment cost: ￥1,500 million ; construction cost: ￥500 million (approx.) / Based on blast furnace with 1 million t/y production[NEDO] (Investment of coal grinding equipment estimated at $50-55/t coal injected [SOACT]) Operating Life : increased life by regular maintenance
4. Effect of Technology Introduction	・Reduction of CO2 Emission	147 kg CO2/t-PI (at 125 kg/t-PI)
	・Fuel Savings	1.55 GJ/t-PI =125*(1/0.7-1)*6200*4.186/1000000 (PCI rate: 125 (=(50+200)/2) kg/t-PI /coke yield : 0.7 / coal heat : 6,917 kcal/kg-coal)
	・Electricity Savings	-
5. Direct Effect (Annual Operating Cost)	・Economic Effect（payback time）	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..[SOACT] Furthermore, coal injection can allow the use of coals of a lower quality compared to coking coals. [*1] payback time; 15.3 years at 125 kg/t-PI years [NEDO]【20 years】
	・Productivity Improvement	Increased productivity[SOACT]
	・Maintenance Cost Reduction	High reliability and easy operation[SOACT] Decreased frequency of BF relining[SOACT]
6. Indirect Effect（Co-benefits）	・Product Quality Improvement	Not announced
	・SOx, Dust Decrease	Not announced
	・Water-saving	Not announced
7. Diffusion Rate of Technology in Japan		well known and familiarized
8. Japanese Main Supplier		* JP Steel Plantech Co. * Nippon Steel Engineering Co., Ltd
9. Technologies Reference:		*1 EU-BAT : 6.3.12.1
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】. * Payback time is defined as (Investment cost / Economical merit) in this project. *Average unit cost of power; ￥15.3/kWh * Refer to "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)"

A-9

Ironmaking

Hot Stove Waste Heat Recovery

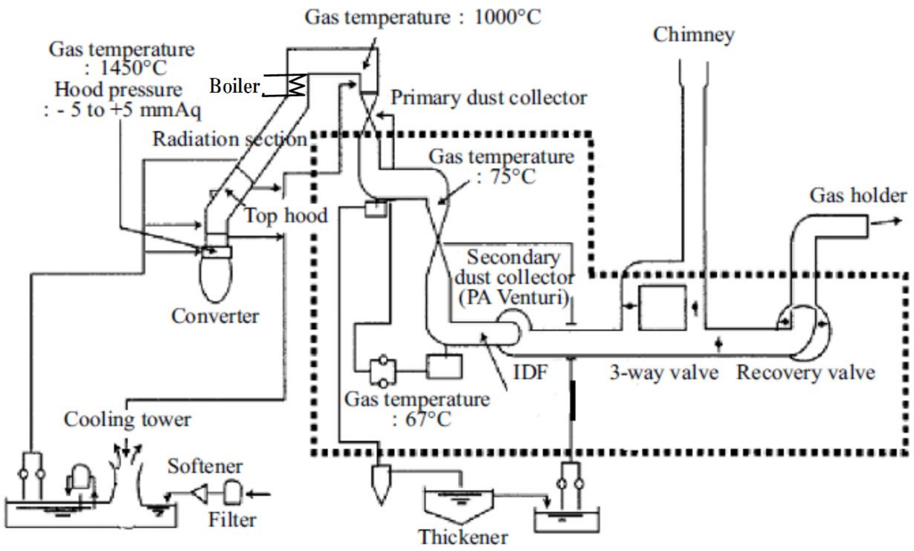
Item		Content
1. Process Flow		 Flow of heat medium-type waste heat recovery device [NEDO]
2. Technology Definition/Specification		This device recovers the sensible heat of the flue gas generated in heating the hot stoves which supply hot blast to the blast furnace and uses this heat in preheating fuel and combustion air for the hot stoves. Installation of this device improves the combustion efficiency of the hot stoves, thereby saving energy. This device (system) comprises two heat exchangers. One is a heat-receiving side heat exchanger which receives the flue gas discharged from the hot stove; the second is a heating side heat exchanger which preheats the combustion air and fuel using the sensible heat of the flue gas received by the heat-receiving side heat exchanger. The preheated combustion air and fuel gas are supplied to the hot stoves. Heat exchange methods are classified as (1) rotary type, (2) plate type, and (3) heat pipe type, depending on the type of heat exchanger. The recovery rate of hot stove flue gas sensible heat with this device is 40-50%.
3. Investment Cost & Operating Life		Equipment: ￥150 million (approx.)【8.9 Crore】/Blast furnace: 1 million t/y (plate type; includes civil construction and installation costs)[NEDO] Operating Life : increased life by regular maintenance
4. Effect of Technology Introduction	・Reduction of CO2 Emission	7.89 kg-CO2/t-CS
	・Fuel Savings	Hot Blast Stove: Fuel savings vary between 83 (=(80+85)/2) MJ/t hot metal [SOACT] 125 MJ/t hot metal [NEDO]
	・Electricity Savings	-
5. Direct Effect (Annual Operating Cost)	・Economic Effect（payback time）	Efficient hot blast stove can run without natural gas [*1] payback time：2.8 years [NEDO]【3.6 years】 = 150*4.186/125/1.81
	・Productivity Improvement	Not announced
	・Maintenance Cost Reduction	Not announced
6. Indirect Effect （Co-benefits）	・Product Quality Improvement	Not announced
	・SOx, Dust Decrease	It might be expected that preheating of the fuel media and a reported increase of the flue-gas temperature would lead to higher NOX emissions from the hot stoves. The application of modern burners may reduce NOX emissions.[*2]
	・Water-saving	Not announced
7. Proficiency Level of Technology in Japan		widely spread and mostly applied
8. Japanese Main Supplier		* Nippon Steel Engineering Co., Ltd.
9. Technologies Reference:		*1 USA-BAT:V.A3.10 *2 EU-BAT: 6.3.14
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】. * Payback time is defined as (Investment cost / Economical merit) in this project. * Refer to http://asiapacificpartnership.org/japanese/soact2nd.aspx and "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)"

A-10		Ironmaking Top Combustion type Hot Stove with Metallic Burners
Item		**Content**
1. Process Flow		Coming Soon
2. Technology Definition/Specification		
3. Investment Cost & Operating Life		
4. Effect of Technology Introduction	• Reduction of CO2 Emission	
	• Fuel Savings	
	• Electricity Savings	
5. Direct Effect (Annual Operating Cost)	• Economic Effect （payback time）	
	• Productivity Improvement	
	• Maintenance Cost Reduction	
	• Effect for converter operations	
6. Indirect Effect （Co-benefits）	• Product Quality Improvement	
	• SOx, Dust Decrease	
	• Water-saving	
7. Proficiency Level of Technology in Japan		
8. Japanese Main Supplier		
9. Technologies Reference:		
10. Preconditions		

A-11

Steelmaking

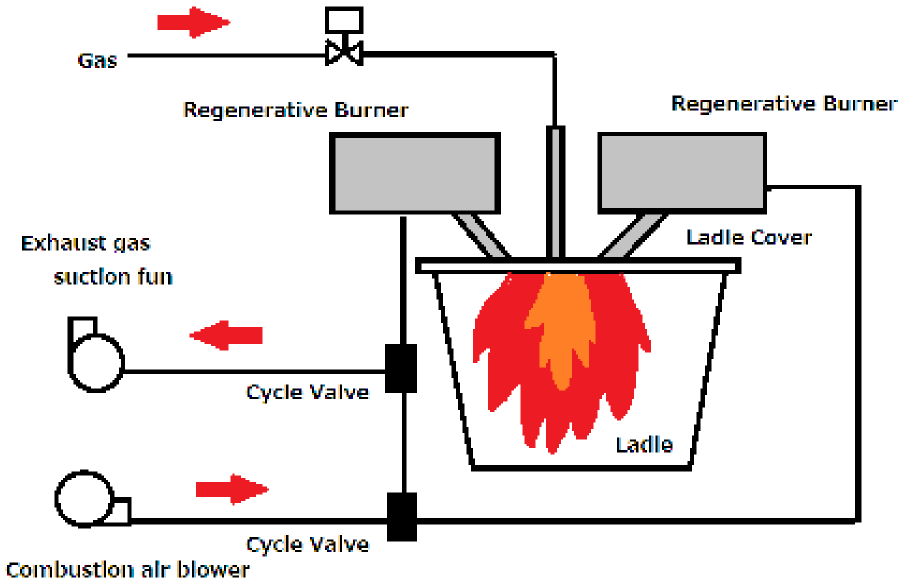
Converter Gas Recovery Device

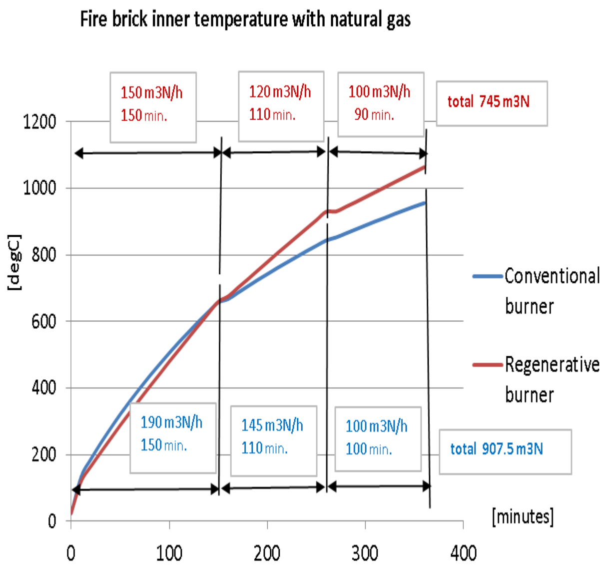
Item		Content
1. Process Flow		 Converter gas recovery device[NEDO]
2. Technology Definition/Specification		Molten steel is produced by the converter process. This device recovers and uses the high temperature waste gas generated in large quantity during blowing in the converter (basic oxygen furnace: equipment used to produce crude steel from pig iron, steel scrap, etc.) Accompanying this process, about 100Nm3 of high temperature gas (CO) with a heating value of approximately 2,000 kcal/Nm3 is generated. Heat recovery methods are classified as (1) combustion method (boiler method) and (2) non-combustion method (method of recovering gas in an unburned condition: OG method. The advanced type is called the closed OG method). Recently, the closed OG method has become the main stream. The OG facilities are designed to recover about 70% of the latent heat and sensible heat. The converter gas recovered is mixed with other by-product gases (coke oven gas, blast furnace gas), then used by the heating equipment of the ironworks. Steam is mainly used by the degassing equipment of the steel making factory.
3. Investment Cost & Operating Life		Equipment cost: ￥600-1,100 million【35～65 Crore】 (equipment for 110 t/charge converter scale; includes construction cost) converter capacity: 110 t/charge.[NEDO] Operating Life : increased life by regular maintenance
4. Effect of Technology Introduction	・Reduction of CO2 Emission	79.8 kg-CO2/t-CS
	・Fuel Savings	0.84 GJ/t-CS [NEDO] =100*2000*4/186/1000000 LDG : 100Nm3/t-CS 2,000kcal/Nm3-OG
	・Electricity Savings	-
5. Direct Effect (Annual Operating Cost)	・Economic Effect（payback time）	Payback time : 8.3～15.2 years (annual crude steel production : 200000 t) [NEDO] The investment required in 2007 was EUR 30.5 million for an ongoing project consisting of a gasholder of 80,000 m3, blower fans, gas ducts, three way valves in the off-gas systems, security measures, erection and engineering, etc. About 80 % of the BOF gas will be recovered resulting in an annual energy savings of 2600 TJ/yr = approximately EUR 12/GJ investment. Payback is about five years taking into account the savings in the purchase of natural gas, exploitation costs. (EU-BAT)
	・Productivity Improvement	Not announced
	・Maintenance Cost Reduction	* 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. * As the steam is produced discontinuously, it cannot always be fully utilized. The use of recovered BOF gas with suppressed combustion is much more flexible. The use of BOF gas in conjunction with blast furnace gas and coke oven gas, allows for the replacement of considerable amounts of primary energy resources, such as natural gas.
	・Effect for converter operations	Increases the IDF efficiency by lowering the temperature of the exhaust gas, achieving high-speed oxygen feeding[SOACT]
6. Indirect Effect （Co-benefits）	・Product Quality Improvement	Not announced
	・SOx, Dust Decrease	* suppressed combustion reduces the quantity of flue-gas and thus reduces the cost of fans and dust removal.[*1]
	・Water-saving	Reduced water requirement for off-gas cooling[*1]
7. Proficiency Level of Technology in Japan		Widely spread and mostly applied
8. Japanese Main Supplier		* JP Steel Plantech Co. * Nippon Steel Engineering Co., Ltd
9. Technologies Reference:		*1 EU-BAT : 7.3.7
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】. * Payback time is defined as (Investment cost / Economical merit) in this project.

A-12

Steelmaking

Low NOx regenerative burner system for ladle preheating

<table>
<tr><th colspan="2">Item</th><th>Content</th></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>


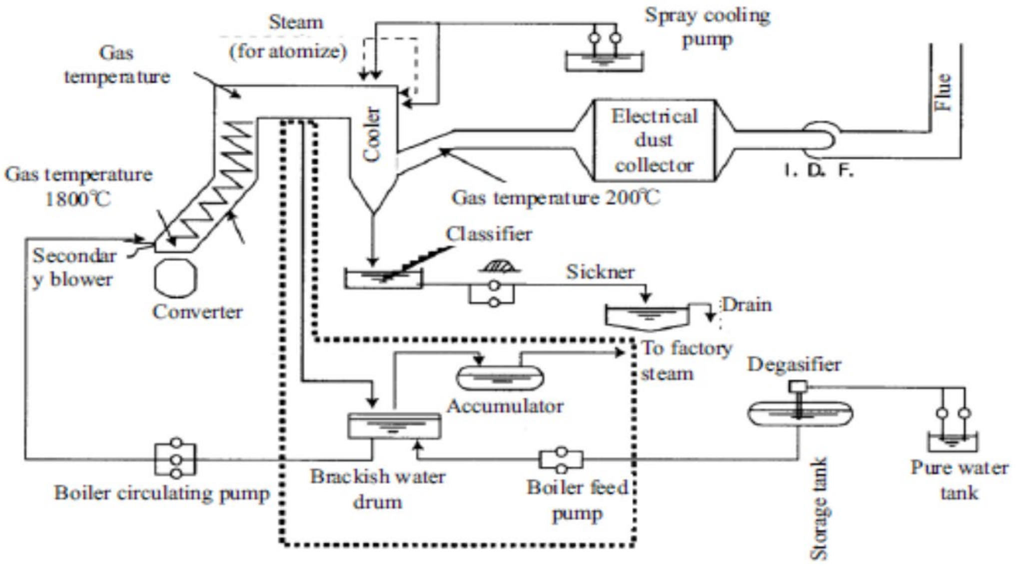


</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>While one of the burners is burning, the other burner will work as an exhaust outlet. The exhaust gas is discharged from the system after the waste heat of the gas is recovered so that the temperature of the gas will be lowered to the extent that there will be no condensation in the regenerator. The combustion air receives heat from the regenerator. Therefore, the combustion air will be preheated to a super-high temperature (i.e., 90% of the temperature of the exhaust gas or over) before the combustion air is supplied to the burner. When the preset cycle time elapses, the burners exchange their roles of combustion and exhaustion.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>・Electricity Saving</td><td>-</td></tr>
<tr><td>・Thermal Energy Savings</td><td>40 % fuel saving is expected comparing to existing preheater with conventional burner.
900 m3N natural gas in 6 hour burning for 80 ton ladle consumes about 40 GJ ---> 0.5 GJ/ton-steel x 40 % = 0.2 GJ/ton-steel save</td></tr>
<tr><td>・Environmental benefits</td><td>Low NOx</td></tr>
<tr><td>・Co-benefits</td><td>Higher brick temperature can allow lower tapping temperature for energy saving at EAF.
Improving meltshop atmosphere by reducing hot gas which disturbs dirty gas suction at the canopy</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai Ro Co., Ltd.　Nippon Furnace CO., LTD</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td></td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

A-13

Steelmaking

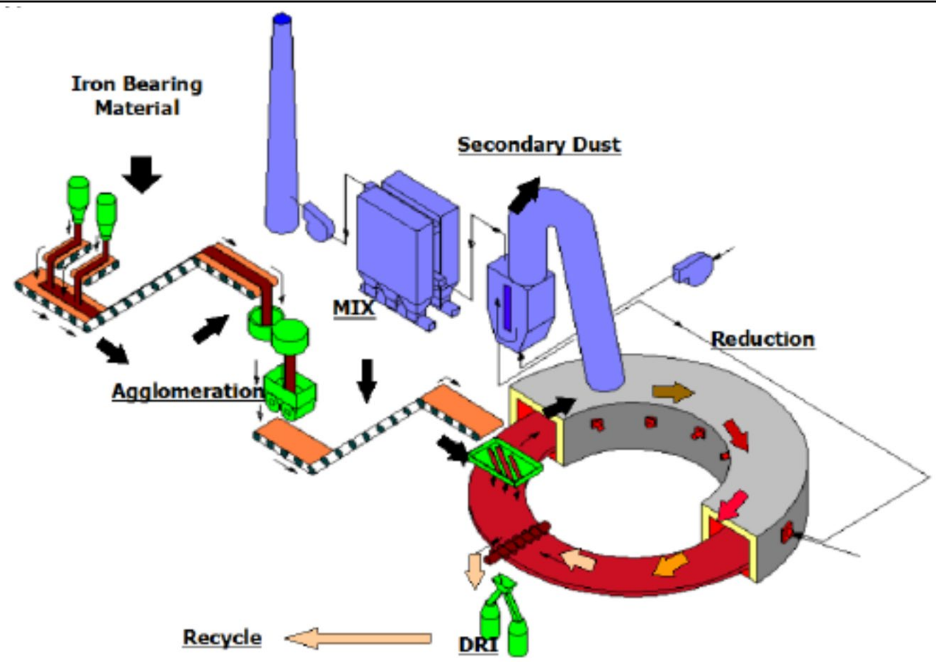
Converter Gas Sensible Heat Recovery Device

Item		Content
1. Process Flow		 Converter gas sensible heat recovery device[NEDO]
2. Technology Definition/Specification		Molten steel is produced by the converter process. This device recovers and uses the high temperature waste gas generated in large quantity during blowing in the converter (basic oxygen furnace: equipment used to produce crude steel from pig iron, steel scrap, etc.) Accompanying this process, about 100Nm3 of high temperature gas (CO) with a heating value of approximately 2,000 kcal/Nm3 is generated. This device recovers and makes efficient use of the converter gas sensible heat. While the converter waste gas recovery device recovers the waste gas itself, this device burns the converter waste gas to transform latent heat to sensible heat and recovers the energy as sensible heat. Therefore, it is structured to have a sufficient space between the converter and the hood so that sufficient air can be supplied from the secondary air blower for combustion. Principal equipments are the brackish water drum, the accumulator, and the boiler etc.
3. Investment Cost & Operating Life		Equipment cost: ￥600 million【35 Crore】 (equipment for 110 t/charge converter scale; includes construction cost) converter capacity: 110 t/charge.[NEDO] Operating Life : increased life by regular maintenance
4. Effect of Technology Introduction	• Reduction of CO2 Emission	11.97kg-CO2/t-CS
	• Fuel Savings	0.126 GJ/t-CS [NEDO] = 30000*4.186/1000000 LDG : 100Nm3/t-CS 30,000kcal/t-cs
	• Electricity Savings	-
5. Direct Effect (Annual Operating Cost)	• Economic Effect (payback time)	Payback time : 44years [NEDO] Energy recovery by means of full combustion systems or suppressed combustion systems is widely applied at oxygen steel plants around the world. There is a tendency towards suppressed combustion systems, mainly because of logistic advantages compared to full combustion systems.(EU-BAT[*1])
	• Productivity Improvement	Not announced
	• Maintenance Cost Reduction	• No need for additional components other than conventional waste heat boiler. • Additional safety engineering measures are not needed other than conventional boiler technologies.
	• Effect for converter operations	Not announced
6. Indirect Effect (Co-benefits)	• Product Quality Improvement	Not announced
	• SOx, Dust Decrease	
	• Water-saving	Reduce temperature of waste water for off-gas cooling
7. Proficiency Level of Technology in Japan		Gas sensible heat recovery system are commomly installed combined with converter gas recovery in Japan.
8. Japanese Main Supplier		JP Steel Plantech Co. Nippon Steel Engineering Co., Ltd
9. Technologies Reference:		*1 EU-BAT : 7.3.7
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】. * Payback time is defined as (Investment cost / Economical merit) in this project. * Refer to "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》 (NEDO, 2008)"

A-14

Recycling and Waste Reduction

Rotary Hearth Furnace Dust Recycling System

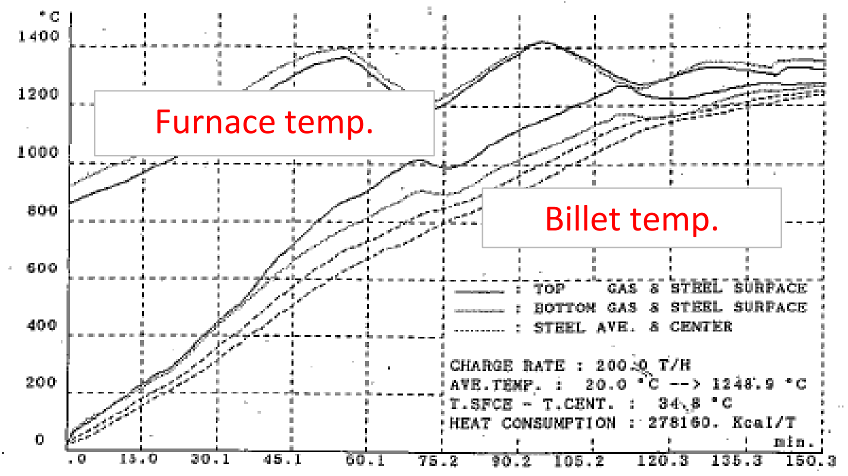
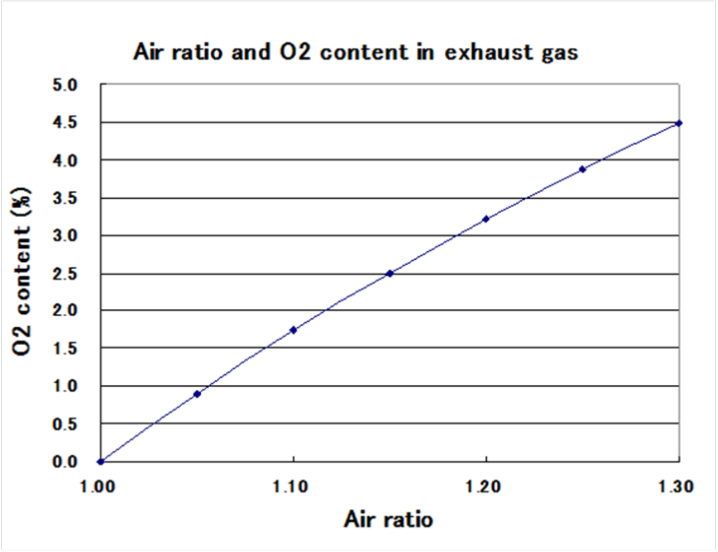
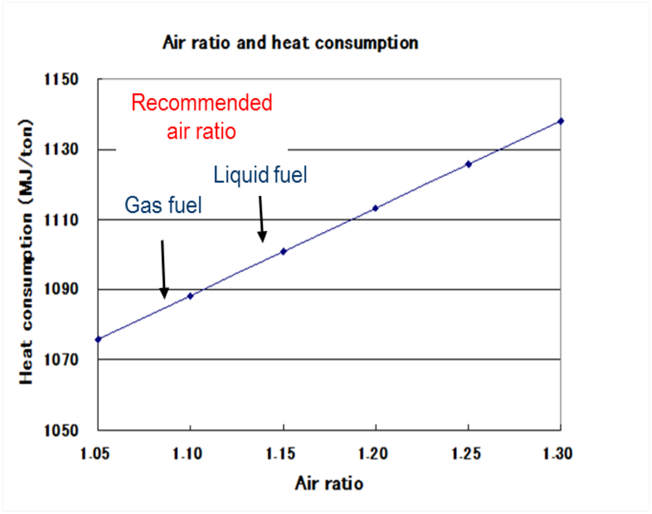
<table>
<tr><th colspan="2">Item</th><th>Content</th></tr>
<tr><td colspan="2">1. Process Flow</td><td>

General process flow of RHF [SOACT]</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>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 once into off-gas.
The exhaust gas containing zinc is cooled using a boiler and recuperator and then, the secondary dust containing condensed zinc is collected in a precipitator.</td></tr>
<tr><td colspan="2">3. Investment Cost & Operating Life</td><td>Comparison of steel mill waste treatment process [*1]
<table>
<tr><th></th><th>Rotary hearth furnace</th><th>Waelz kiln</th><th>Melt kiln</th><th>Electrical furnace type</th><th>Shaft furnace type</th></tr>
<tr><td>Zinc removal rate</td><td>90 - 97%</td><td>75 - 90%</td><td>99%</td><td>99%</td><td>99%</td></tr>
<tr><td>Maximum design capacity (10^3 t / y)</td><td>400 - 500</td><td>80</td><td>60</td><td>30 - 50</td><td>50 - 80</td></tr>
<tr><td>Investment cost per capacity</td><td>1</td><td>3</td><td>3 - 4</td><td>4 - 8</td><td>3 - 4</td></tr>
<tr><td>Operation cost</td><td>1</td><td>1.5 - 2.0</td><td>1.5 - 2.0</td><td>2 - 3</td><td>2 - 3</td></tr>
<tr><td>Others</td><td></td><td colspan="2">Sticking problem on kiln wall</td><td></td><td></td></tr>
<tr><td>Total evaluation</td><td>Superior</td><td>Base</td><td>Base</td><td>Base</td><td>Base</td></tr>
</table>
Fixing investment cost is difficult due to large effect of plant scale.
Operating Life : increased life by regular maintenance</td></tr>
<tr><td rowspan="3">4. Effect of Technology Introduction</td><td>・Reduction of CO2 Emission</td><td>22.5 kg-CO2/t-PI [SOACT & NSC]
= 0.23 (kg-coke/kg-DRI) x 30(kg-DRI/t-PI) x 3.257(kg-CO2/kg-coke)[WS Guidebook]</td></tr>
<tr><td>・Fuel Savings</td><td>0.21GJ/t-PI [SOACT & NSC]
=0.23(kg-coke/kg-DRI) x 30(kg-DRI/t-PI) x 30.1(MJ/kg-coke) x 0.001(GJ/MJ)[WS Guidebook]
・Decrease in fuel(coke) ratio to BF is up to 0.23(kg-coke/kg-DRI) [SOACT] ,
・NCV(Net Calorific Value) of coke : 30.1(MJ/kg-coke)[WS Guidebook]
・(DRI;30(kg/t-PI))[* 1]</td></tr>
<tr><td>・Electricity Savings</td><td>-</td></tr>
<tr><td rowspan="3">5. Direct Effect （Annual Operating Cost ）</td><td>・Economic Effect (payback time)</td><td>Operating Life : increased life by regular maintenance</td></tr>
<tr><td>・Productivity Improvement</td><td>Not announced</td></tr>
<tr><td>・Maintenance Cost Reduction</td><td>Not announced</td></tr>
<tr><td rowspan="3">6. Indirect Effect （Co-benefits）</td><td>・Product Quality Improvement</td><td>Not announced</td></tr>
<tr><td>・SOx, Dust Decrease</td><td>• Waste reduction and decreased disposal costs
• Extended landfill life
• Recovery of unused resources (recycling iron, nickel, zinc, carbon, etc.)[SOACT]
In the sinter or cold pellet process, almost all the zinc contained in the raw material is directly transferred to the product. Because of the above limits on the permissible amount of zinc that can be contained in the blast furnace burden, dust containing a large amount of zinc could not be used as a raw material and hence was simply discarded. After the dust recycling plants, employing an RHF, were put into operation, it has become possible to remove zinc from the dust and hence recycle almost all the dust and sludge generated within the works.[*1]</td></tr>
<tr><td>・Water-saving</td><td>Not announced</td></tr>
<tr><td colspan="2">7. Proficiency Level of Technology in Japan</td><td>well known and familiarized</td></tr>
<tr><td colspan="2">8. Japanese Main Supplier</td><td>* Nippon Steel Engineering Co., Ltd.</td></tr>
<tr><td colspan="2">9. Technologies Reference:</td><td>*1 : NIPPON STEEL TECHNICAL REPORT No. 86 p.35(July 2002)
https://www.nipponsteel.com/en/tech/report/nsc/pdf/8608.pdf</td></tr>
<tr><td colspan="2">10. Preconditions</td><td>* Refer to http://asiapacificpartnership.org/japanese/soact2nd.aspx</td></tr>
</table>

A-15

Processing

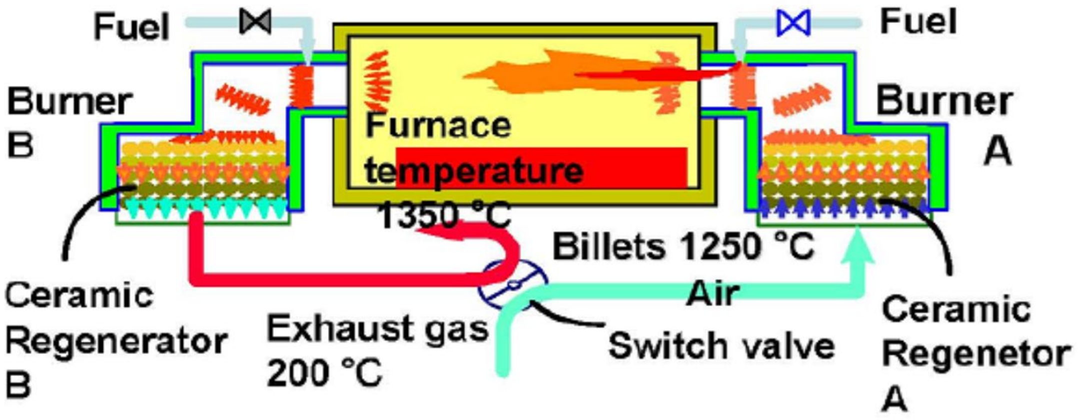
Process control for reheating furnace

Item		Content
1. Process Flow or Diagram		  
2. Technology Definition/Specification		- Setting furnace temperature by targeted billet temperature curve - Precise air ratio control and O2 analysis in exhaust gas
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	0.05 GJ/ton-product (3.5 % fuel saving from the base line of 1,450 MJ/ton)
	･Environmental benefits	-
	･Co-benefits	-
4. Japanese Main Supplier		Chugai Ro Co., Ltd.　Rozai Kogyo Kaisha Ltd.
5. Technologies Reference		May contact to Chugai-Ro
6. Comments		-

A-16

Processing

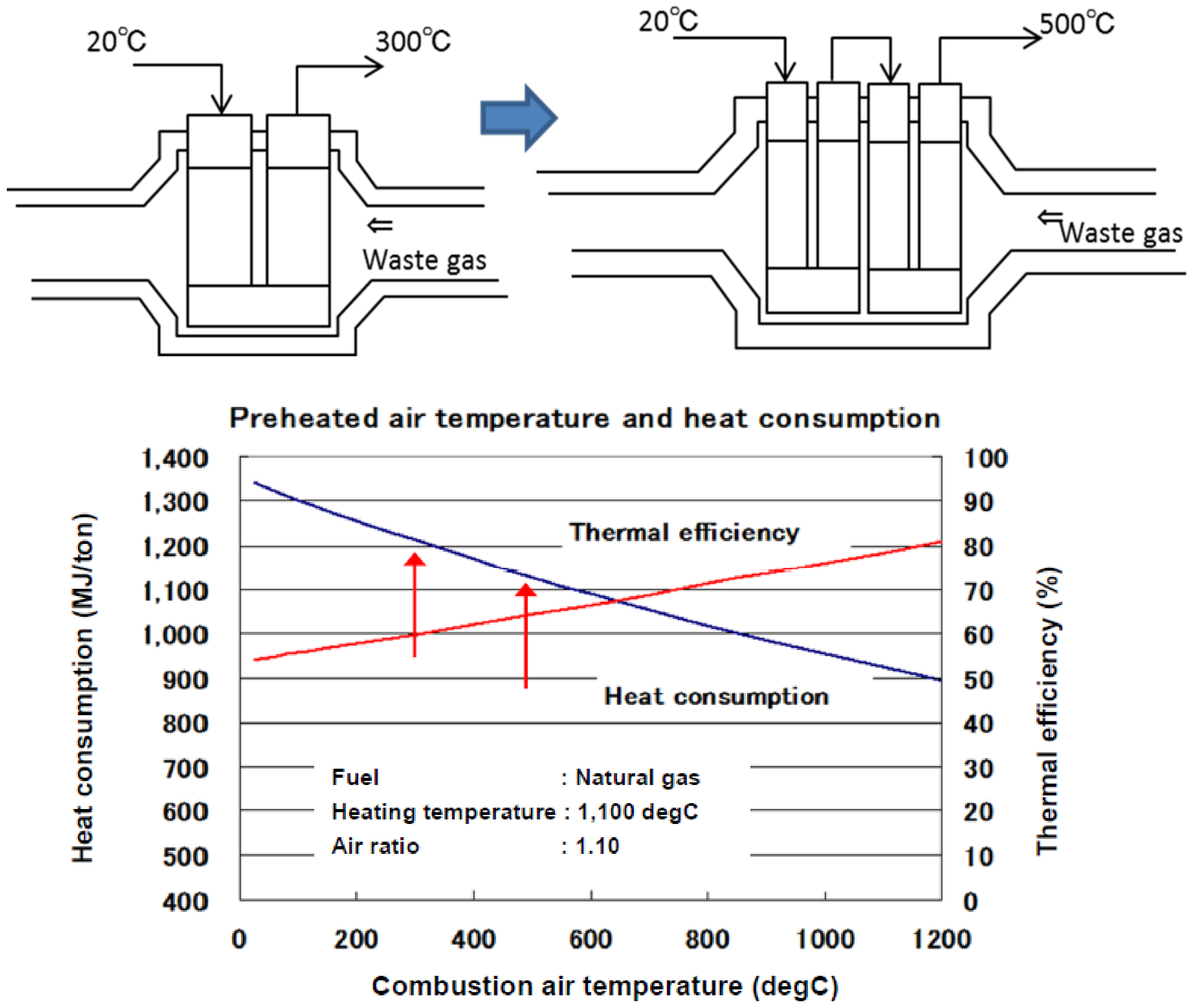
Regenerative Burner Total System for reheating furnace

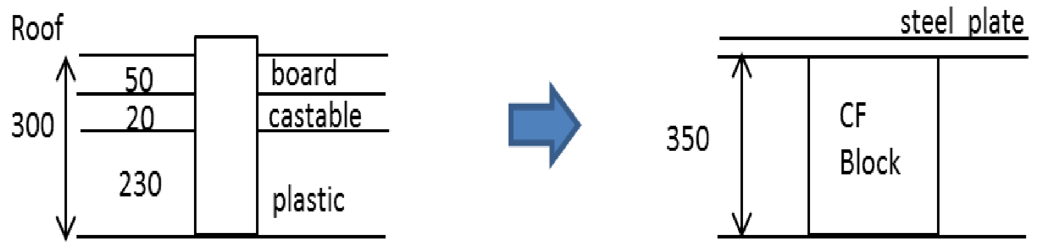
Item		Content
1. Process Flow		 Application of regenerative burner [SOACT]
2. Technology Definition/Specification		An unit, Burner with Regenerator, ensures highly efficient, selectable thermal storage: ・The burner body is compact and of mono-block construction incorporating a valve to select air or exhaust gas. ・The whole system can be downsized with a reduction in cost. ・This product is applicable to compact high-temperature furnaces where the introduction of conventional regenerative systems is difficult. ・The regenerative media uses an alumina ball that is economical and excellent in heat resistance and corrosion resistance. ・The product is ideal for forge furnaces, open flame heat treatment furnaces, nonferrous metal melting furnaces, and other high-temperature furnaces that are comparatively compact in capacity.
3. Investment Cost & Operating Life		Not announced
4. Effect of Technology Introduction	・Reduction of CO2 Emission	10.66 kg-CO2/t-CS
	・Fuel Savings	0.19 (=(0.17+0.21)/2) GJ/t-CS【1.9 Crore】
5. Direct Effect (Annual Operating Cost)	・Economic Effect（payback time）	Not announced
	・Productivity Improvement	Expected
6. Indirect Effect （Co-benefits）	・Environmental effect	・Quiet operation [*1] ・NOx decrease
7. Diffusion Rate of Technology in Japan		well known and familiarized
8. Japanese Main Supplier		Chugai Ro Co., Ltd. [*1] Nippon Furnace CO., LTD [*2] Nippon Steel Engineering Co., Ltd Rozai Kogyo Kaisha Ltd.
9. Technologies Reference:		*1: http://www.chugai.co.jp/ *2: http://www.furnace.co.jp/
10. Preconditions		・Basic condition; amount of productionis 0.2 million ton of billet per year at EAF plant * Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】. * Payback time is defined as (Investment cost / Economical merit) in this project.

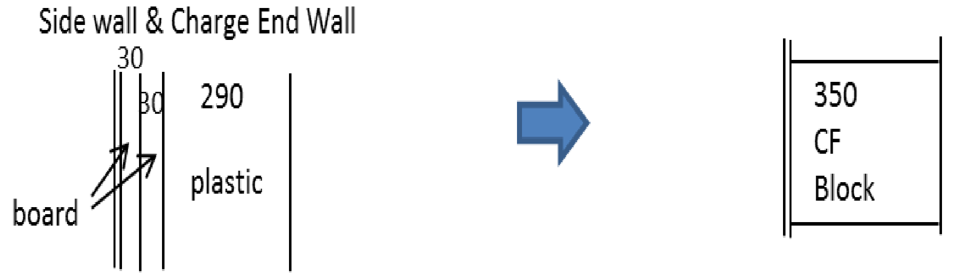
A-17

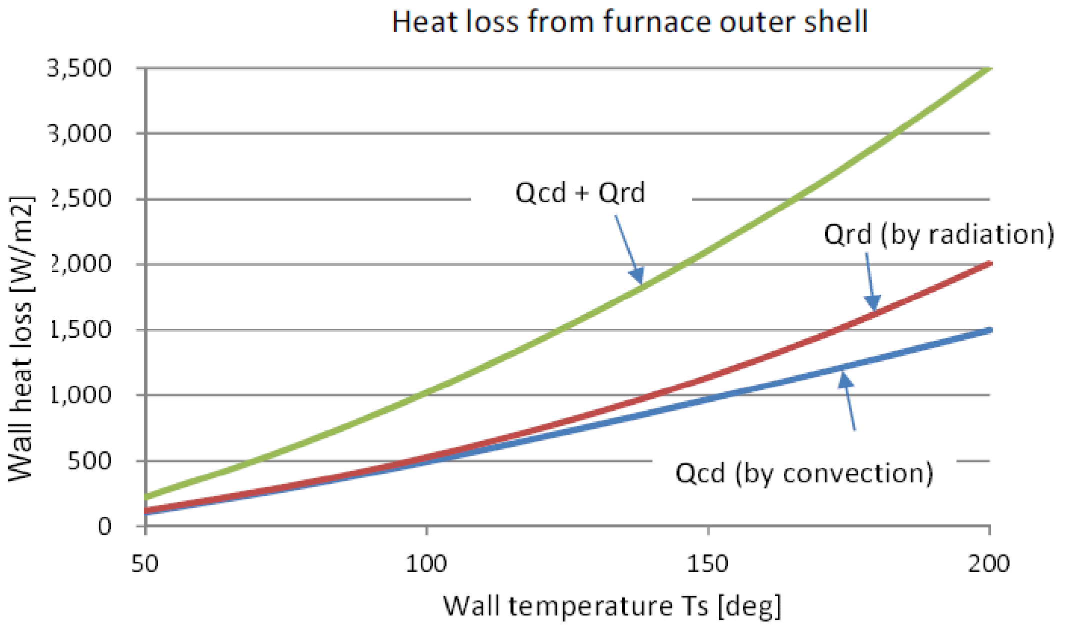
Processing

High temperature recuperator for reheating furnace

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		Heat transfer area of the existing recuperator shall be increased (for example, by changing two-pass to four-pass) in order to raise the preheated combustion air temperature. For this purpose, the followings may or may not be needed. - Modification of Recuperator room - Change of air duct - Increase in discharge pressure of blower - High grade recuperator material
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	0.100 GJ/t (about -7%)
	･Environmental benefits	CO2 Reduction
	･Co-benefits	-
4. Japanese Main Supplier		Chugai Ro Co., Ltd. Rozai Kogyo Kaisha Ltd.
5. Technologies Reference		Diagram from Chugai Ro
6. Comments		<Preconditions on calculating effects> When 300 degC air temperature is raised to 500 degC

<table>
<tr><td colspan="2"><h1>A-18</h1></td><td><h2>Processing</h2><h3>Fiber block for insulation of reheating furnace</h3></td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>






- Atmosphere temp. Tatm = 30 degC
- Emissivity Es = 0.85

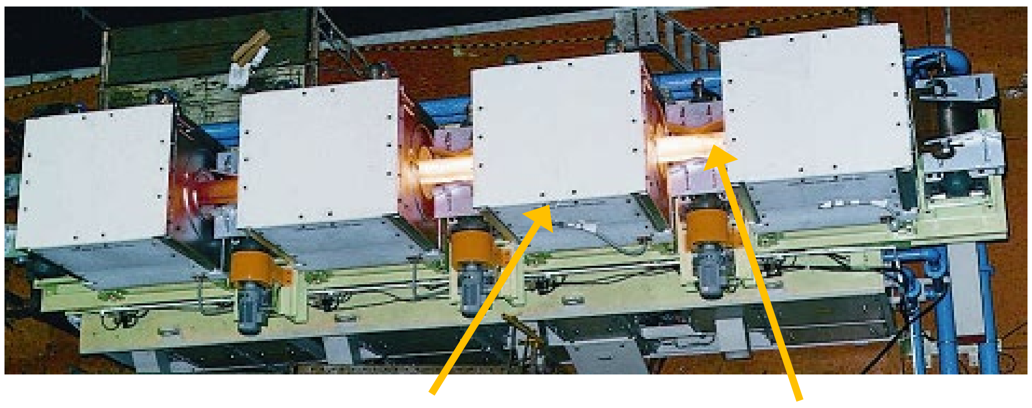
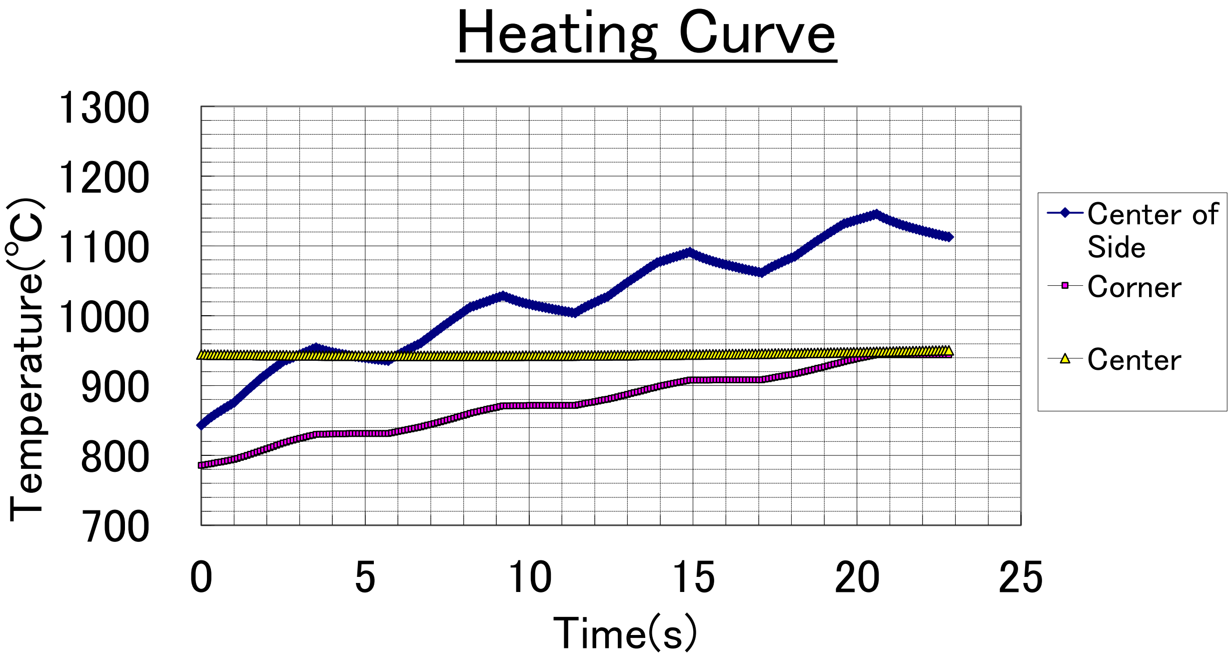
$$Qs = 2.44\times(Ts-Tatm)^{1.25} + 5.674/10^{8}\times\varepsilon_{s}\times((Ts+273.15)^{4}-(Tatm+273.15)^{4}$$ [W/m2]

(1 [kcal/h･m2] = 0.86 x 1 [W/m2])
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>Ceramic fiber is lighter in weight and has the lower thermal conductivity than conventional brick or castable.
Ceramic fiber can be used for the insulation of furnace roof and side wall.</td></tr>
<tr><td rowspan="4">3. Expected Effect of Technology Introduction</td><td>･Electricity Saving</td><td>-</td></tr>
<tr><td>･Thermal Energy Savings</td><td>0.039 GJ/t (about 2.7 %)</td></tr>
<tr><td>･Environmental benefits</td><td>Reduction of Heat accumulation</td></tr>
<tr><td>･Co-benefits</td><td>Quick heat-up and cool-down of the furnace temperature for smooth and energy-saving operation.</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai Ro Co., Ltd.　Rozai Kogyo Kaisha Ltd.</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from Chugai Ro and JP Steel Plantech</td></tr>
<tr><td colspan="2">6. Comments</td><td><Preconditions on calculating effects>
assumed surface area of 100 ton/h furnace : 1350 m2
atmosphere temperature : 30 degC
surface temp. and heat loss of brick lining case : 130 degC, 7.96 GJ/h
surface temp. and heat loss of brick lining case :   90 degC, 4.08 GJ/h
(7.96 - 4.08) /100 (ton/h) = 0.0388 GJ/ton ---> 0.039 GJ/ton saving
<Notice>
High-sulphur fuel may cause problem due to the corrosion of fixing pins.</td></tr>
</table>

A-19

Processing

Induction type billet heater for direct rolling

Item		Content
1. Process Flow or Diagram		 Induction coil Hot billet 
2. Technology Definition/Specification		Compensate temperature drop of billets transferred from CC to rolling mill (from 950 degC to 1050 degC). Advantages : - Automatic control - Less exhaust gas (without reheating furnace)
3. Expected Effect of Technology Introduction	･Electricity Saving	40 kWh/ton-product increase (electrical energy for billet heating)
	･Thermal Energy Savings	1.45 GJ/ton-product (Cold charge to reheating furnace is replaced.)
	･Environmental benefits	Better working floor and atmosphere
	･Co-benefits	-
4. Japanese Main Supplier		Mitsui E&S Power Systems Inc.
5. Technologies Reference		-
6. Comments		MESPS Tokyo Office: TEL 03-6806-1075 FAX 03-5294-1121

A-20

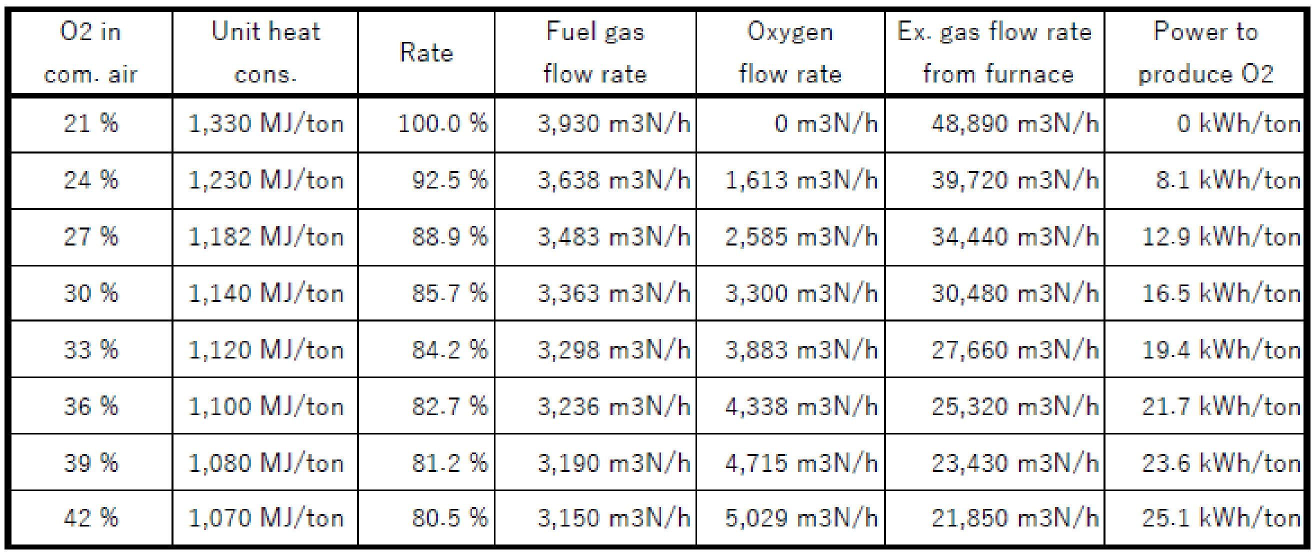
Processing

Oxygen enrichment for combustion air

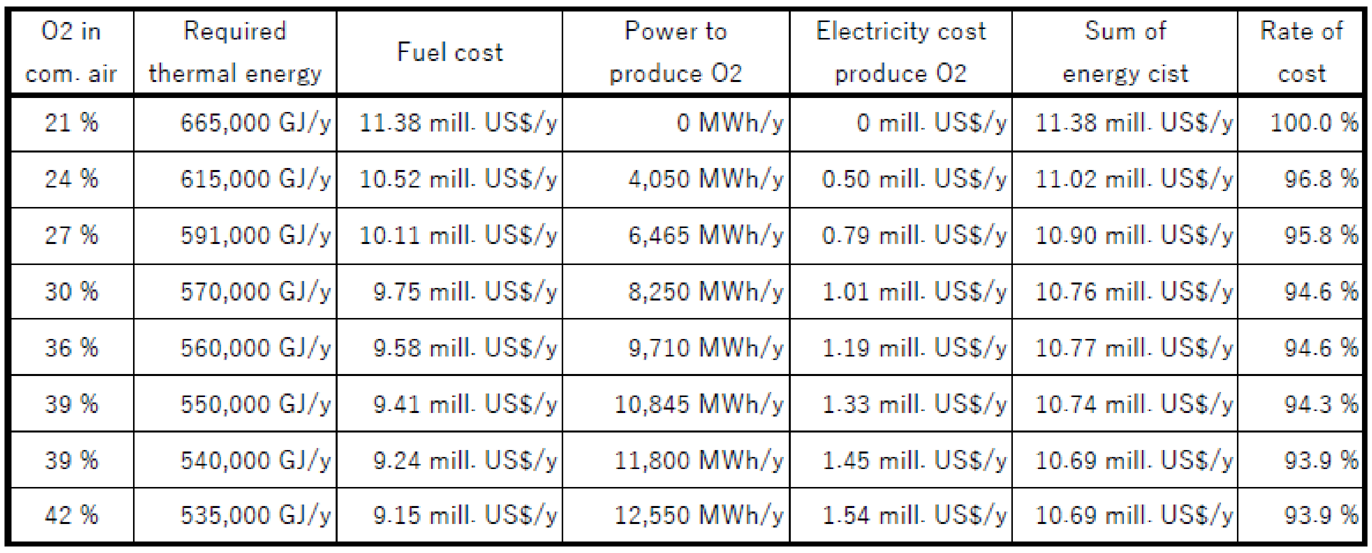
Item	Content
1. Process Flow or Diagram	When oxygen is mixed into combustion air to increase the O2 percentage, thermal energy will be reduced with the decrease in the volume of exhaust gas. In many EAF plants, oxygen is generated by PSA or VPSA process, therefore, new equipment for oxygen generation is not considered in this sheet. Only the electric power to generate oxygen is studied to estimate its economical effect.

2. Technology Definition/Specification

Effects of oxygen enrichment are studied for the model RHF of 100 ton/h 1,100 degC billet heating (500,000 ton/y). The upper list shows the required fuel (thermal energy) and volume of oxygen. When oxygen percentage is raised to 42 %, exhaust gas volume from the furnace reduces to 45 % with 19.5 % fuel saving. The list also shows the required oxygen volume. The oxygen is assumed to be generated by VPSA process, with the purity of 93 %.
The bottom list shows the economical effect of oxygen enrichment. Required electric power is assumed as 0.5 kWh/m3N-O2 of 0.1 MPa pressure. Energy price is based on the latest Japanese values of 17.11 US$/GJ and 0.123 US$/kWh.



O2 in com. air	Unit heat cons.	Rate	Fuel gas flow rate	Oxygen flow rate	Ex. gas flow rate from furnace	Power to produce O2
21 %	1,330 MJ/ton	100.0 %	3,930 m3N/h	0 m3N/h	48,890 m3N/h	0 kWh/ton
24 %	1,230 MJ/ton	92.5 %	3,638 m3N/h	1,613 m3N/h	39,720 m3N/h	8.1 kWh/ton
27 %	1,182 MJ/ton	88.9 %	3,483 m3N/h	2,585 m3N/h	34,440 m3N/h	12.9 kWh/ton
30 %	1,140 MJ/ton	85.7 %	3,363 m3N/h	3,300 m3N/h	30,480 m3N/h	16.5 kWh/ton
33 %	1,120 MJ/ton	84.2 %	3,298 m3N/h	3,883 m3N/h	27,660 m3N/h	19.4 kWh/ton
36 %	1,100 MJ/ton	82.7 %	3,236 m3N/h	4,338 m3N/h	25,320 m3N/h	21.7 kWh/ton
39 %	1,080 MJ/ton	81.2 %	3,190 m3N/h	4,715 m3N/h	23,430 m3N/h	23.6 kWh/ton
42 %	1,070 MJ/ton	80.5 %	3,150 m3N/h	5,029 m3N/h	21,850 m3N/h	25.1 kWh/ton



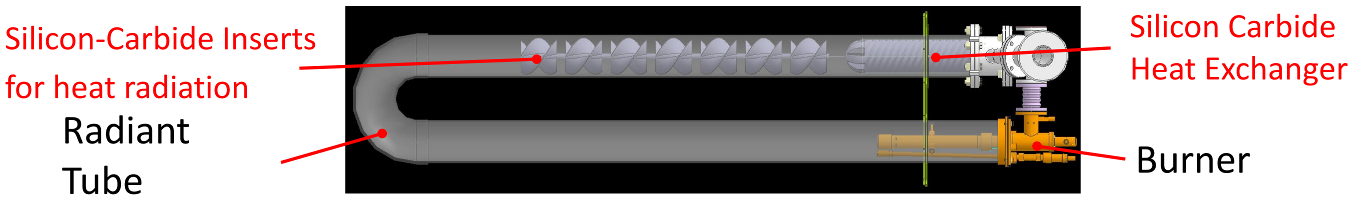
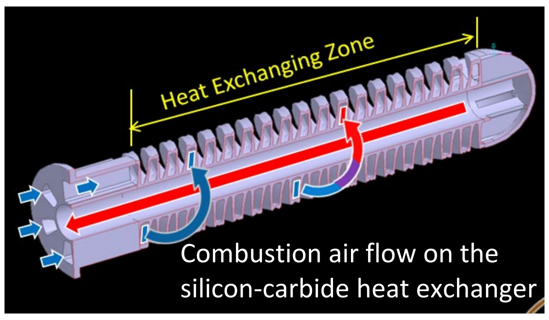
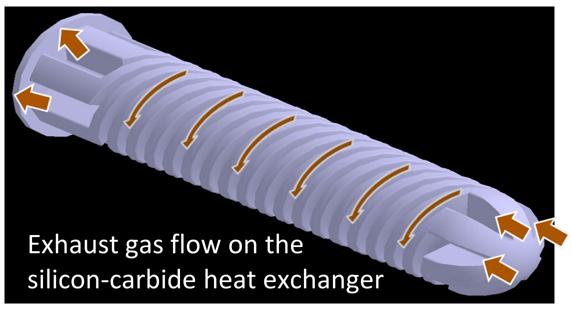
O2 in com. air	Required thermal energy	Fuel cost	Power to produce O2	Electricity cost produce O2	Sum of energy cist	Rate of cost
21 %	665,000 GJ/y	11.38 mill. US$/y	0 MWh/y	0 mill. US$/y	11.38 mill. US$/y	100.0 %
24 %	615,000 GJ/y	10.52 mill. US$/y	4,050 MWh/y	0.50 mill. US$/y	11.02 mill. US$/y	96.8 %
27 %	591,000 GJ/y	10.11 mill. US$/y	6,465 MWh/y	0.79 mill. US$/y	10.90 mill. US$/y	95.8 %
30 %	570,000 GJ/y	9.75 mill. US$/y	8,250 MWh/y	1.01 mill. US$/y	10.76 mill. US$/y	94.6 %
36 %	560,000 GJ/y	9.58 mill. US$/y	9,710 MWh/y	1.19 mill. US$/y	10.77 mill. US$/y	94.6 %
39 %	550,000 GJ/y	9.41 mill. US$/y	10,845 MWh/y	1.33 mill. US$/y	10.74 mill. US$/y	94.3 %
39 %	540,000 GJ/y	9.24 mill. US$/y	11,800 MWh/y	1.45 mill. US$/y	10.69 mill. US$/y	93.9 %
42 %	535,000 GJ/y	9.15 mill. US$/y	12,550 MWh/y	1.54 mill. US$/y	10.69 mill. US$/y	93.9 %

Item		Content
3. Expected Effect of Technology Introduction	･Electricity Saving	When oxxygen percentage is raised to 39 %, 23.6 kWh/ton of electricity is needed.
	･Thermal Energy Savings	When oxxygen percentage is raised to 39 %, 0.26 GJ/ton of thermal energy is saved.
	･Environmental benefits	-
	･Co-benefits	-
4. Japanese Main Supplier		Chugai Ro Co., Ltd.　Nippon Furnace CO., LTD　Rozai Kogyo Kaisha Ltd.
5. Technologies Reference		-
6. Comments		Furnace manufactureres can arrange the oxygen control system and piping revamping.

A-21

Processing

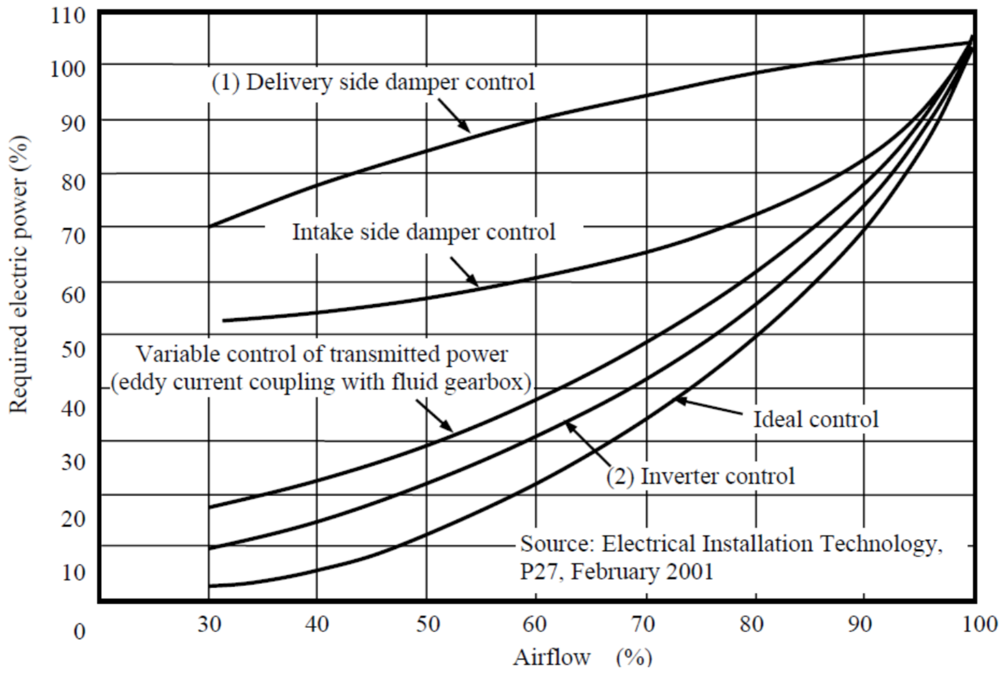
Highly efficient combustion system for radiant tube burner

Item		Content
1. Process Flow		  
2. Technology Definition/Specification		Radiant tube burner which consists of 1)Radiant tube(U shape or W shape), 2)Gas Burner, 3)3-D formed silicon-carbide Inserts for heat radiation, and 4)Heat exchanger made of 3-D formed silicon carbide. These 3-D formed silicon carbide elements have high thermal conductivity and wide surface area, which allow approx. 10% improvement in heat recovery compared to conventional radiant tube burners with heat exchanger made of steel. Any industrial furnace with radiant tube burner will potentially be applicable and typical applicable furnace will be CGL, Continuous Galvalizing Line or CAL, Continuous Annealing Line, with approx. 100-200 radiant tube burners of 210-420MJ/hour of rated combustion volume. *Radiant tube burner is often used for the industrial furnaces such as heat treatment furnace which requires indirect heating.
3. Investment Cost & Operating Life		The cost of adding this system into existing furnace will be approximately 1.6 million JPY for one burner which have 420MJ/hour of combustion rate. This includes the cost for installation work and combustion adjustments. Operating life for silicon carbide elements is considered to be semipermanently.
4. Effect of Technology Introduction	• Reduction of CO2 Emission	2,654t-CO2/year under assumptions below. 1) 10% of Fuel substitution will be achieved by replacing conventional recupecator into DINCS (Daido Innovative Neo Combustion System) to the CGL with 200 radiant tube burners. 2) Each burners have 420MJ/h of rated combustion volume, and combusted at 80% rate on average. 3) Furnace operation is 330days/year, 24 hours/day. Production capacity is assumed as 594,000 ton/y (75 ton/h x 24h x 330 day/y) 4) The effect is calculated as comparison with steel heat exchanger system 5) Natural gas is used as for combustion. $53222(GJ/year) \times 0.0136(tC/GJ) \times {}^{44}/_{12} = 2{,}654(tCO2/year)$
	• Fuel Savings	53,222GJ/year under assumptions same as above 0.0896 GJ/ton saving (= 53,222 GJ/y / 594,000 ton-product/y)
	• Electricity Savings	N/A
5. Direct Effect (Annual Operating Cost)	• Economic Effect (payback time)	Approx. 4.9 years under assumptions same as above. Cost for installation work and combustion adjustment are included (1,600,000JPY) and the price of thermal enrgy is assumed to be 19.11 US$/GJ (2,100 JPY/GJ). Annual profit = 53,222 GJ/y x 19.11 US$/GJ / 594,000 ton/y = 1.71 US$/ton-product <Calcuation> Payback time = (1,600,000 JPY x 200 units) / (53,222 GJ/y x 2,100 JPY/GJ) = 2.86 year
	• Productivity Improvement	Since this system transfers the heat effectivly into the furnace or into product, line speed of the furnacecan be increased which results in productivity improvement, if there is no restrictions for the equpment other than the combustion system.
	• Maintenance Cost Reduction	Conventional heat exchanger made of steel usually requires replacement every 3-4 years, but silicon carbide elements will not deteriorate over time and last semipermanently.
6. Indirect Effect (Co-benefits)	• Product Quality Improvement	N/A
	• SOx, Dust Decrease	N/A
	• Water-saving	N/A
7. Proficiency Level of Technology in Japan		Applied to more than 30 heat treatment furnaces.
8. Japanese Main Supplier		Daido Steel Co., Ltd.
9. Technologies Reference:		Japanese patent No.6587411 (Radiant tube type heating device) Japanese patent No.6790554 (Radiant tube type heating device)
10. Preconditions		Investment cost and benefit vary depending on furnace specification, operation condition, fuel cost, etc of each customer.

A-22

General Energy Saving & Environmental Measures

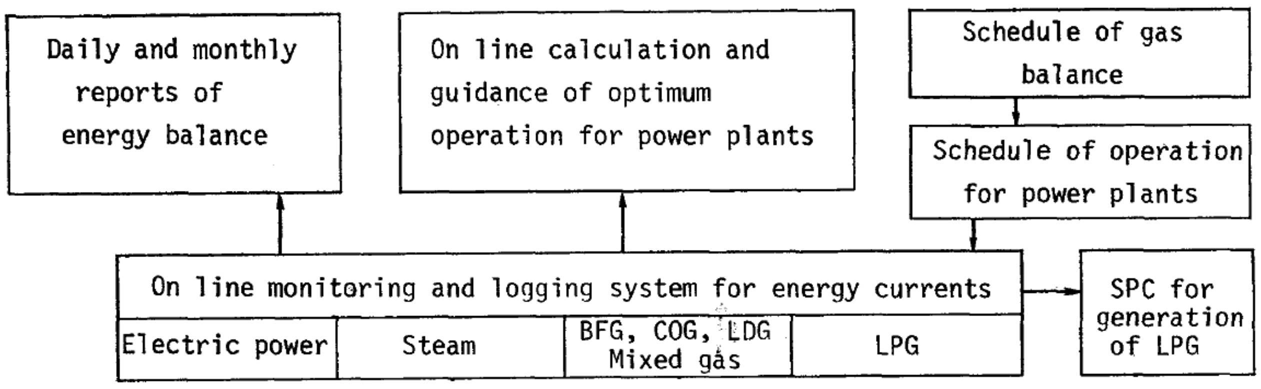
Inverter (VVVF; Variable Voltage Valuable Frequency) **Drive for Motors**

Item		Content
1. Process Flow		 Source: Electrical Installation Technology, P27, February 2001 Relationship between airflow under airflow control and the required Electric power
2. Technology Definition/Specification		An inverter is a variable speed device controlling frequency and voltage to allow precise control of rotation. The commercial AC voltage is converted to DC in the converter control unit, which then controls the inverter to generate a three-phase variable voltage and variable frequency current. A high-pressure inverter as an energy-saving device can directly drive a high-speed electric motor without using a booster transformer. High-pressure IGBT (Insulated Gate Bipolar Transistor) inverter device outputs high voltage of 3.3kV and 6.6kV, depending on the single-phase inverter multiple connection technology. Energy saving effect : Conversion of six 55kW electric motors with eddy current coupling, and reduction in power consumption Calculation conditions/NEDO : * Overall efficiency of conventional electric motors with eddy current coupling : 0.65 * Overall efficiency of electric motors converted to inverter control : 0.80 * Reduction in power consumption by lowering motor speed : 15% (assumed) * Annual operation : 3,600 h/y * Unit cost of power : ￥15/kWh
3. Investment Cost & Operating Life		￥2,000,000/unit(assumed) [NEDO]【0.12 Crore/unit】
4. Effect of Technology Introduction	･Reduction of CO2 Emission	Not announced
	･Electricity Savings	90,000 kWh/y [NEDO]【0.04 Crore/unit】
5. Direct Effect (Annual Operating Cost)	･Economic Effect（payback time）	1.5 years [NEDO]【2.9 years】
	･Productivity Improvement	Not announced
	･Maintenance Cost Reduction	Not announced
6. Indirect Effect （Co-benefits）	･Product Quality Improvement	Not announced
7. Diffusion Rate of Technology in Japan		No data
8. Japanese Main Supplier		major electric equipment suppliers
9. Technologies Reference:		Energy savings Diagnosis Examples-Common Equipment Volume', Energy conservation Center, Japan Sumiyasu Kodama, et al. "High-performance AC Drive Series for Industrial Use", Toshiba Review, 52, 9, 1997, p.36-39
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】. * Payback time is defined as (Investment cost / Economical merit) in this project. * annual operation : 3,600 h/y * unit cost of power : ￥15/kWh * Note : SOACT data - Electricity savings 42 % - payback time : 3.4 years (3 pence/kWh under US 1994 conditions) * Refer to http://asiapacificpartnership.org/japanese/soact2nd.aspx and "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)"

A-23

General Energy Saving & Environmental Measures

Energy Monitoring and Management Systems

Item		Content
1. Process Flow		 Energy Monitoring and Management Systems
2. Technology Definition/Specification [*1]		This measure includes site energy management systems for optimal energy recovery and distribution between various processes and plants. The aim of energy management should be to maximize the productive use of gases arising from the processes, thereby minimizing the necessity of importing supplementary energy sources into the system and optimizing the specific energy consumption within the inherent constraints of the system. In order to achieve the goal, there must be an adequate system dealing with the technical possibilities and costs on the one hand, and on the organization on the other hand. 1.Optimizing energy consumption: Typically, a change in the energy supply of one process in the steel plant influences several other processes (e.g. the use of coke oven gas in the blast furnace can result in a higher caloric value in the BF top gas). Optimizing tools that consider the whole integrated site may be preferable to ones that consider each process as a standalone unit. 2. Online monitoring.: This is often used for the most important energy flows and combustion processes at the site. The data are stored for a long time so that typical situations may be analyzed. Very important is the online monitoring for all gas flares. It is the main technique used to avoid energy losses in the flares and combustion processes. 3. Continuous monitoring systems: For all energy-related process parameters can be used to optimize process control and enable instant maintenance, thus achieving an undisrupted production. 4. Reporting and analyzing tools.: Reporting tools are often used to check the average energy consumption of each process. In connection with cost controlling, controlling energy is the basis for optimizing energy consumption and cost savings. An energy controlling system offers the possibility of comparing actual data with historical data (e.g. charts) 5. Techniques to optimize process gas utilization：Some potential process-integrated techniques used to improve energy efficiency in an integrated steelworks by optimizing process gas utilization include: (1) the use of gas holders for all by-product gases or other adequate systems for short-term storage and pressure holding facilities for maximizing the recovery of process gases. (2) increasing pressure in the gas grid if there are energy losses in the flares – in order to utilize more process gases with the resulting increase in the utilization rate. (3)reheating fire furnaces with process gas in order to maximize the use of process gases and reduce the need to purchase natural gas or electrical power. (4)use of a computer-controlled caloric value control system. This measure includes site energy management systems for optimal energy recovery and distribution between various processes and plants.
3. Investment Cost & Operating Life		It depends on system structure, from data monitoring network to whole control computer system. One example in Netherlands (was aquired by Tata Steel, and nominal capacity is 6.3Mt/y.) is \$0.8M.【4.3 Crore】
4. Effect of Technology Introduction	・Reduction of CO2 Emission	11.4 kg-CO2/t-steel
	・Fuel Savings	0.12 GJ/t-steel [*2, 3]
	・Electricity Savings	Not announced
5. Direct Effect（Annual Operating Cost）	・Economic Effect（payback time）	Depends on cost of fuel and electricity of each site.
	・Maintenance Cost Reduction	Not announced
6. Indirect Effect（Co-benefits）	・Product Quality Improvement	Not announced
7. Diffusion Rate of Technology in Japan		widely spread and mostly applied
8. Japanese Main Supplier		Major electric equipment suppliers
9. Technologies Reference:		*1 EU-BAT 2.5.2.1 9.1.2, USA-BAT IV.A9.2 *2 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 ETSU, 1992. "Reduction of Costs Using an Advanced Energy Management System," Best Practice Programme, R&D Profile 33, Harwell, UK:ETSU
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】.

A-24

General Energy Saving & Environmental Measures

Cogeneration (include Gas Turbine Combined Cycle (GTCC))

Item		Content
1. Process Flow		Coming Soon
2. Technology Definition/Specification		
3. Investment Cost & Operating Life		
4. Effect of Technology Introduction	• Reduction of CO2 Emission	
	• Fuel Savings	
	• Electricity Savings	
5. Direct Effect (Annual Operating Cost)	• Economic Effect （payback time）	
	• Productivity Improvement	
	• Maintenance Cost Reduction	
6. Indirect Effect （Co-benefits）	• Product Quality Improvement	
	• SOx, NOx, Dust Decrease	
	• Water-saving	
7. Proficiency Level of Technology in Japan		
8. Japanese Main Supplier		
9. Technologies Reference:		
10. Preconditions		

A-25

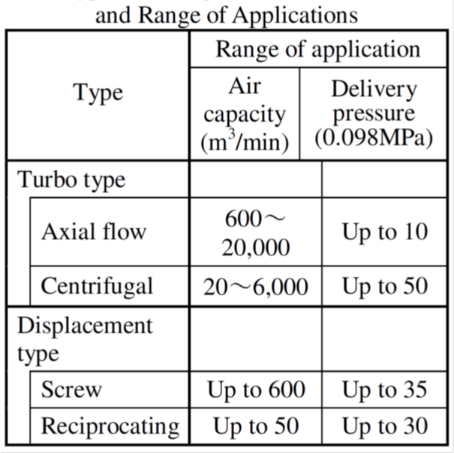
General Energy Saving & Environmental Measures

Management of Compressed Air Delivery Pressure Optimization

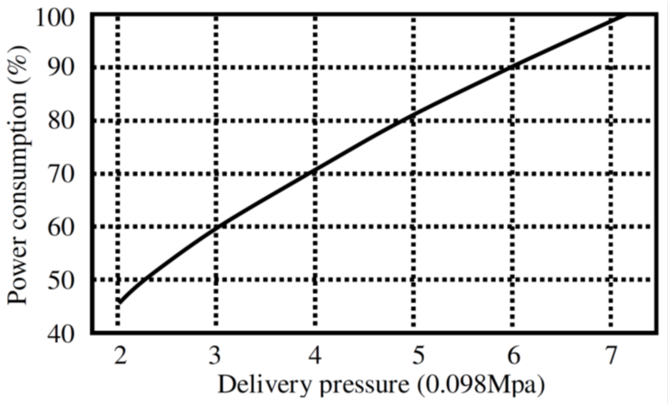
Item	Content

1. Process Flow

Types of Compressors Available, and Range of Applications



Type	Range of application	
	Air capacity (m^3/min)	Delivery pressure (0.098MPa)
Turbo type		
Axial flow	600～20,000	Up to 10
Centrifugal	20～6,000	Up to 50
Displacement type		
Screw	Up to 600	Up to 35
Reciprocating	Up to 50	Up to 30



Relationship Between Delivery Pressure and Power consumption (with fixed delivery capacity)

2. Technology Definition/Specification

The delivery pressure of compressors is generally 100 kPa or higher. Compressors have been developed for a variety of applications. Table shows the types of compressors available, and their range of applications.
Energy saving in compressors requires consideration of the following points.

* Selection of the appropriate capacity
* Reduction in delivery pressure

Since the required motive power increases with increased delivery pressure, delivery pressure should be reduced as much as possible, while at the same time being sufficient for the receiving equipment (Fig.), however it should be noted that motive power does not decrease with delivery pressure in the case of turbo compressors.

* Prevention of leakage
* Reduction in temperature of the compressed air
* Reduction in intake air resistance

Intake air resistance increases with intake filters, silencers, and valves in piping etc, and will increase the required motive power if excessive. Care is required to reduce pressure losses in the intake air system through periodic cleaning of filters to eliminate clogging.

* Reduction in piping resistance

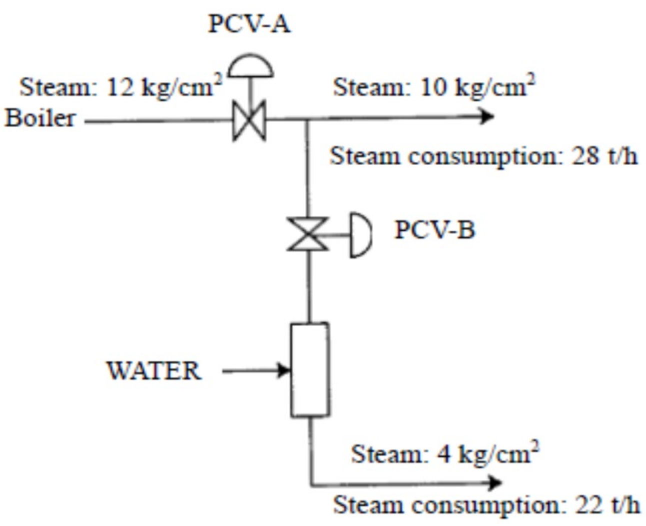
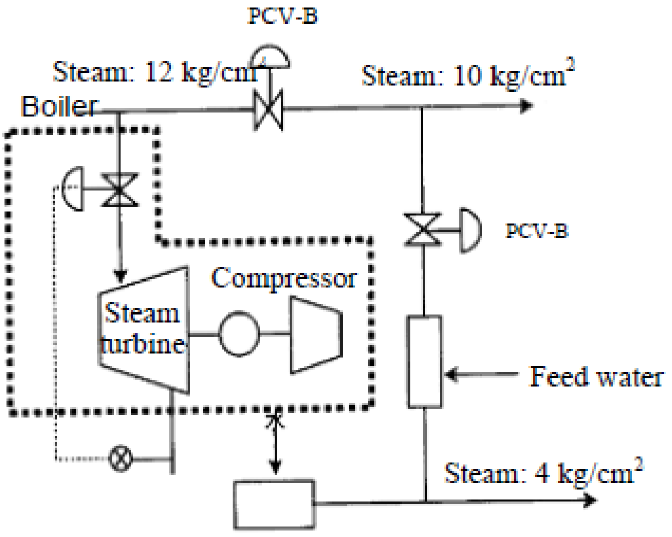
Calculation conditions;
*Number of compressors; Total of 17, *Delivery pressure; 0.8MPa,
*Equipment capacity; 823 kW, *On-load operation load; 60%,
*Daily operation; 24 h/d, *Annual operation; 241 days

3. Investment Cost & Operating Life		Not announced
4. Effect of Technology Introduction	・Reduction of CO2 Emission	Not announced
	・Electricity Savings	285 MWh/y (=823 kW * 60 % * 10 % * 24 h/d * 241 days/y)
5. Direct Effect (Annual Operating Cost)	・Economic Effect (payback time)	Not announced
	・Monetary equivalent of energy savings	￥4,370,000/y【0.5 Crore/year】
	・Maintenance Cost Reduction	Not announced
6. Indirect Effect (Co-benefits)	・Product Quality Improvement	Not announced
7. Diffusion Rate of Technology in Japan		well known and familiarized
8. Japanese Main Supplier		Major electric equipment suppliers
9. Technologies Reference:		‘Energy saving Diagnosis Examples – Common Equipment Volume’, Energy conservation Center, Japan
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in【】. * Payback time is defined as (Investment cost / Economical merit) in this project. * Average unit cost of power; ￥15.3/kWh

A-26

General Energy Saving & Environmental Measures

Power Recovery by Installation of Steam Turbine in Steam Pressure Reducing Line

Item		Content
1. Process Flow		 Fig. 1 Steam pressure reducing system before improvement  Fig. 2 System after improvement by introduction of steam turbine
2. Technology Definition/Specification		**<u>Outline</u>** : In cases where high pressure steam generated by a boiler is used by pressure reduction, this technology reduces refrigerator power consumption by installing a steam turning in place of the steam pressure reducing valve and driving the refrigerator with the power recovered by the steam turbine. Although steam consumption is increased somewhat, a total energy saving is achieved. **<u>Principle, operation and features of technology</u>**: In this example in **Fig.1**, the capacity of the boiler which had been installed was approximately steam pressure: 12 kg/cm2 and steam output: 50 t/h. However, this steam was used as process steam after pressure reduction. In one case, the reduced-pressure conditions were 10 kg/cm2 and 28t/h, and in another, 4 kg/cm2 and 22t/h (approximate values). That is, steam at a pressure of 12 kg/cm2 was reduced to 10 kg/cm2 and 4 kg/cm2 by pressure reducing valves. In this example in **Fig.2**, a steam turbine is used in place of a pressure reducing valve, and the system was modified so that a refrigerator is driven by the rotational force of the turbine using steam as a power source. Pressure reducing valves reduce pressure by causing a pressure loss when the valve port in the valve is restricted, utilizing the difference in enthalpy drop due to adiabatic restriction. The principle of the steam turbine is the same as this, in that power is generated by utilizing the difference in enthalpy drop. The energy saving by adoption of this system is as follows: Reduction of electric power consumption – fuel for increase of steam consumption = Energy saving
3. Investment Cost & Operating Life		approx. 50 million (Equipment), approx. 20million (Construction)
4. Effect of Technology Introduction	・Reduction of CO2 Emission	Not announced
	・Electricity Savings	544 (approx.) kW → 544kW*24h*330d/y=4308 MWh/y Demerit: Increase of steam consumption, approx.0.8 (t-steam/h)
5. Direct Effect (Annual Operating Cost)	・Economic Effect（payback time）	6,197.6(Gcal/y)=(Electricity Savings : 114,00.2Gcal/y)-(Increase of Steam consumption : 5,202.6Gcal/y) Reduction in crude oil equivalent: 619.8 t-crude oil/y (approx.) Equipment only : 0.7 years (approx.)【5.8 years】, Including construction cost: 1.0 years (approx.)【8.1 years】
	・Monetary equivalent of energy savings	￥68 million/y【0.5 Crore/y】
	・Maintenance Cost Reduction	Not announced
6. Indirect Effect (Co-benefits)	・Product Quality Improvement	Not announced
7. Diffusion Rate of Technology in Japan		Numerous examples of implementation of similar technologies at main plants in Japan.
8. Japanese Main Supplier		Kobe Steel, Ltd.
9. Technologies Reference:		・FY2000 Study Report “Survey of Energy Saving in Japan,” New Energy and Industrial Technology Development Organization (NEDO), March 2001 ・“Collected Examples of Energy Saving,” p. 1,095, 1984 (in Japanese)
10. Preconditions		* Important values were revised with referring to various values in "1-4. Used values and applied preconditions." Especially as for investment cost and payback time for the case of India, revised values were indicated in 【】. * "Japanese Technologies for Energy Savings/ GHG Emissions Reduction 《2008 Revised Edition》(NEDO, 2008)" Cost of power：¥17.99/kWh Cost of C heavy oil：¥1.81/1,000kcal Overall boiler efficiency: 0.8 Electricity conversion factor: 2646kcal/kWh Steam conversion factor: 656.9kcal/kg-steam

1. Energy-Saving Technologies

1-3. Used Values and applied preconditions

	Items	unit	Value	Reference
1. Electricity (Power) Conversion Factor	**Electricity**	GJ/MWh (kcal/kWh)	**11.4 (2,717)**	PAT_Rules_English.pdf(2012/3), p37
2. Fuel Calorific Value	**Oil (Crude Oil)**	kcal/kg	**10,000**	Ministry of Power Notification S.O.394(E), 12th March, 2007
	Coal	kcal/kg	**6917 ***	referred to Answer Sheet from India
3. Energy Cost	**Electricity**	unit/kWh	**4.48Rs ****	Annual Report 2011-2012 on the working of State Power Utilities & Electricity Departments, Planning Commission, Government of INDIA October, 2011, p150
	C Heavy Oil	unit/Mcal	**2.04Rs**	Energy Prices and Taxes/IEA Statistics/2012
	Coal	unit/Mcal	**1.4Rs ***	referred to Answer Sheet from India
4. CO2 Emission Factor	**Electricity**	t-CO2/MWh	**0.903**	average of combined margin from CDM projects, IGES website (29th May, 2018)
	Coke Oven Gas	t-CO2/GJ	**0.044**	referred to Answer Sheet from India
	Coke	t-CO2/t-coke	**3.257**	
	Coal	t-CO2/GJ	**0.095**	
	Steam	t-CO2/t-steam	**0.195**	
	Natural Gas	kg-CO2/GJ	**51.32**	worldsteel/IEA
	Unspecified Fuel	t-CO2/GJ	**0.095**	referred to Answer Sheet from India
5. Current Exchange Rate	Rs/￥		**0.59**	at the current exchange rate in 20th Jan., 2013
	Rs/$		**53.7**	
	Rs/Won		**0.05**	

* : average value

** : average value in all power plants supplying electricity to Steel Works

2. Environmental Protection Technologies

2-1. Technologies Customized List

Technologies Customized List of Environmental Protection Technologies for Indian Steel Industry 2022 version part 1:BF-BOF (v.5.0)

No.	Title of Technology	Technical Description	Expected Effects of Introduction
Waste Water Treatment			
B-1	High-Speed Coagulating Sedimentation Equipment	- Injection of polymer and optimized agitating time to produce high density pellets	- Removing suspended solids (SS)
B-2	High-Speed Filtration Equipment	- Combined cleaning with the air and water cleans the filter well and restores it completely	- Removing suspended solids (SS)
B-3	Multi-Staged Fluidized-Bed Activated Carbon Absorption Equipment	- The multi staged fluidized bed all allows for continuous feed and extraction of activated carbon	- Removing organic substance and oil - Decoloration of colored wastewater
B-4	High-Speed Air Flotation System	- Ten times larger upflow velocity than the conventional system, leading to drastic reduction in installation space	- Removing oily and suspended matters
B-5	Cooling Tower	- Equipped with the blower module consisting of reliable blower/ speed reducer/ motor and filling materials of high heat exchange efficiency	- Removing naphthalene and dust
B-6	Electrochlorination System	- This system reduces the volume of acid cleaning waste water, with the recycle system of MGPS	- Reduction of acid cleaning waste water
Reduction of SO2 from Coke Oven gas by Desulphurization			
B-7	Reduction of SO2 from Coke Oven gas by Desulphurization	- The NNF Process is the latest desulfurization process for COG, which does not produce the contaminated waste water	- Minimizing SO2 emission
Dust Emissions Control			
B-8	Wet type Electrostatic Precipitator for COG	- Tar separation from COG with stable performance and continuous operation	- Low outlet dust (tar) concentration < 1 mg/ Nm^3
B-9	Dry type Electrostatic Precipitator	- The precipitator structure and dimensions have been standardized to uniform the gas flow distribution	- Low outlet dust concentration < 10-50 mg-dust/Nm^3
B-10	Moving Electrode Electrostatic Precipitator: MEEP	- A moving electrode mechanism and a new method that removes dust by means of brushes were developed	- Cleaning exhaust gas (dust and ultrafine dust) from sintering machines
B-11	Wet type Electrostatic Precipitator for Scarfing Machine	- Dust, mist and submicron particulate are collected on collecting plates and washed away by water sprays	- Cleaning exhaust gas (dust and mist) from scarfing machines to less than 1 mg/m^3
B-12	Wet type Electrostatic Precipitator for By-Produced Gas Turbine	- Using water in removing the collected dust, the wet EP can achieve high dust removal efficiency less than 1 mg/Nm^3	- Effective for SO$_3$, PM 2.5 and heavy metals
Exhaust Gas Treatment through Denitrification, Desulphurization			
B-13	Dry Activated Coke Exhaust Gas Treatment Facilities	- This method is capable of eliminating DXNs and heavy metals such as Hg in exhaust gas	- Eliminating DXNs and heavy metals such as Hg in exhaust gases
Blast Furnace Gas and Cast House Dedusting			
B-14	Multi-Vessel Electrostatic Precipitator (MVEP)	- Dust and water drops are removed by electric energy in MVEP located in the gas turnover/rising section in each vessel, which generates clean gas	- Realizing the dust content at the outlet of 5 mg/Nm$_3$ or lower
B-15	Ring Slit Washer (RSW) Wet Gas Scrubber	- Achieved excellent dust collection performance with its low load differential pressure and liquid-gas ratio	- Realizing the dust content at the outlet of 5 mg/Nm^3 for BFG or 20 mg/Nm^3 for LDG
B-16	Pulse type Bag Filter	- Compressed air is discharged through the pulsing nozzle and creates shock wave breaking the dust cake deposition	- Eliminating dust, DXNs and others
B-17	High temperature filter bag(nanolof HT)	- High temperature resistance up to Max 350℃ - Non-flammable material (High resistance for sparks) - High strength (approximately 30% stronger than regular filter bag) - Easy handling and installation compared to ceramic forming filter bag.	- Less damage from sparks. - Energy and utility cost saving can be achieved due to omission or downside of existing cooling facility.
General Technology			
B-18	Gas Analyzer	- Measures the NO, SO2, CO2, CO, CH4, N2O and O2 components in sample gas by detecting the amount of infrared rays absorbed by a Measuring cell, with Mass flow sensor.	- Quantitative grasp of substances of atmosphere that cause global warming

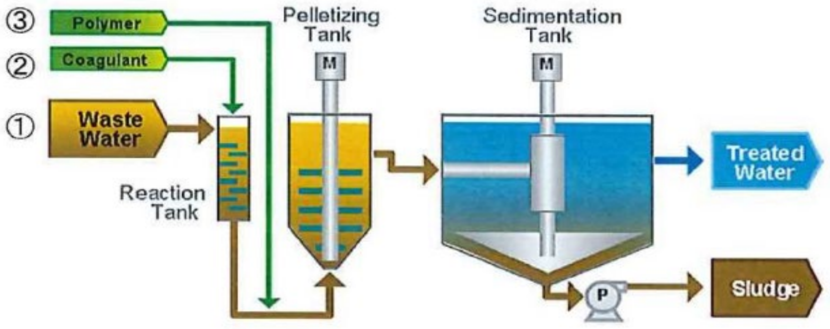
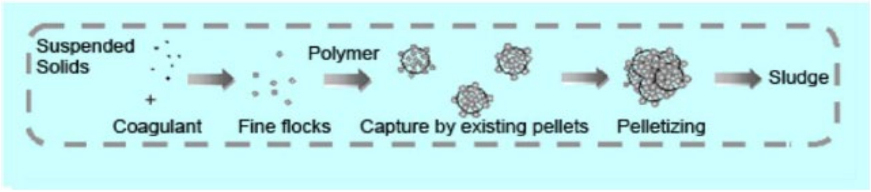
2. Environmental Protection Technologies

2-2. Technologies One by One Sheet

B-1

Waste Water Treatment

High-Speed Coagulating Sedimentation Equipment

Item	Content
1. Process Flow or Diagram	 **Flow of High-Speed Sedimentation Treatment** 
2. Technology Definition/Specification	1. Suitable coagulants are selected according to wastewater property in order to generate high-density flocks. 2. Injection of polymer and optimized agitating time to produce high-density pellets. 3. Sedimentation & settlement process A slurry blanket layer is formed to quicken the sedimentation of the consolidated pellets
3. Field of Application	Removing SS from various types of wastewater
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) Environmental Water Quality Standard http://www.env.go.jp/en/water/
5. Benefits	Not Announced
6. Co-benefits	・No sludge thickener is required. Sludge is thickened to a high concentration (approx. 30,000 milligram/liter) by consolidation.
7. Japanese Main Supplier	Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.
8. Technologies Reference	https://power.mhi.com/group/es/products/rainwater/outline

B-2

Waste Water Treatment

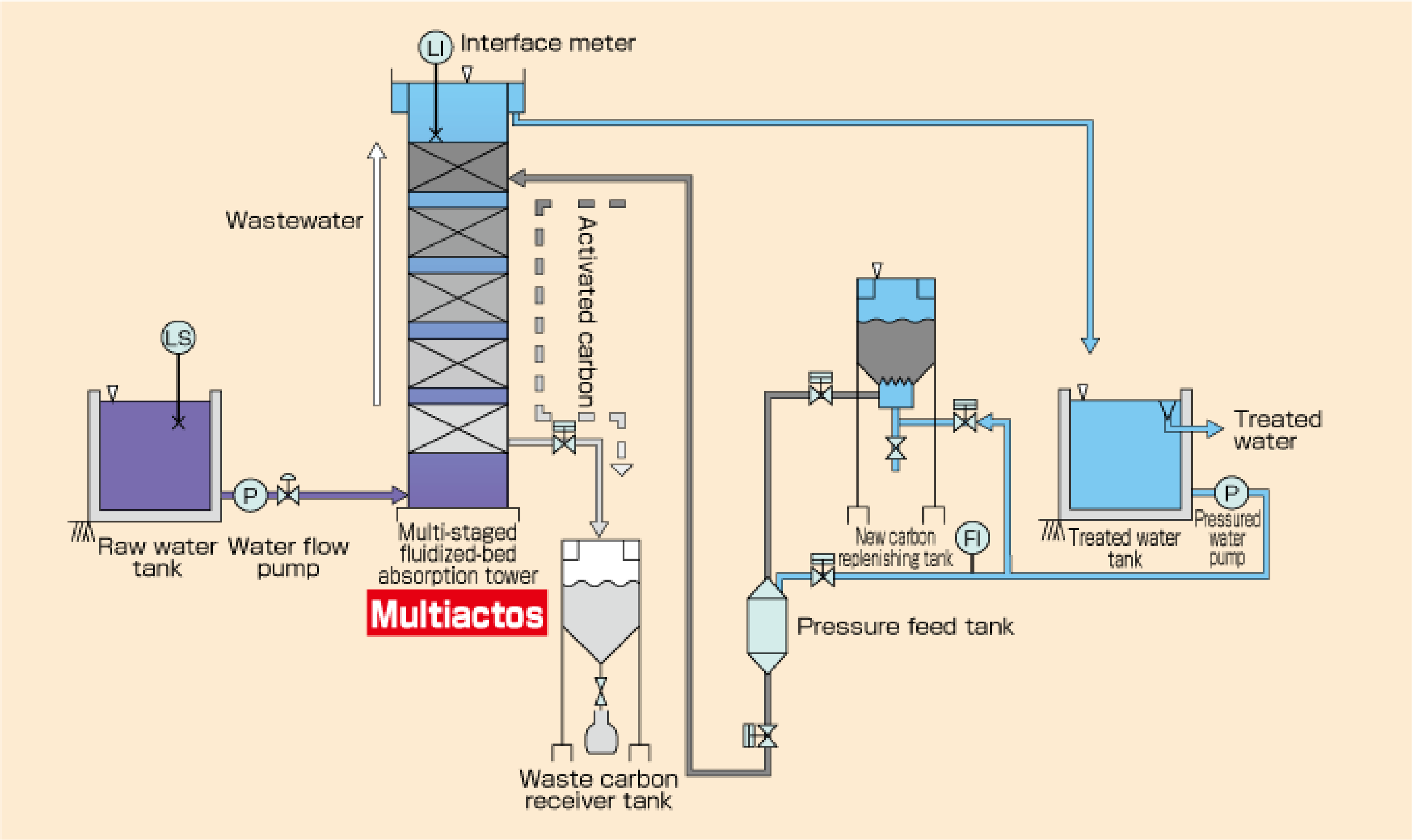
High-Speed Filtration Equipment

Item	Content
1. Process Flow or Diagram	
2. Technology Definition/Specification	- Excellent filter cleaning Combined cleaning with the air and water cleans the filter well and restores it completely. - Easy operation management All operations are automatically controlled, which makes the operation management so easy.
3. Field of Application	This is most commonly used at a steel plant for blooming and continuous caster, and their equipment can be backed up with stability.
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) Environmental Water Quality Standard http://www.env.go.jp/en/water/wq/wp.pdf
5. Benefits	Stable operation : With strong tolerance against variation of inflow raw water quality, the system can obtain filtered water stably, which can make the operation so stable.
6. Co-benefits	Not Announced
7. Japanese Main Supplier	Kobelco Eco-Solutions Co., Ltd
8. Technologies Reference	https://www.kobelco-eco.co.jp/english/product/pdf/industrial_water_treatment/superfilter.pdf

B-3

Waste Water Treatment

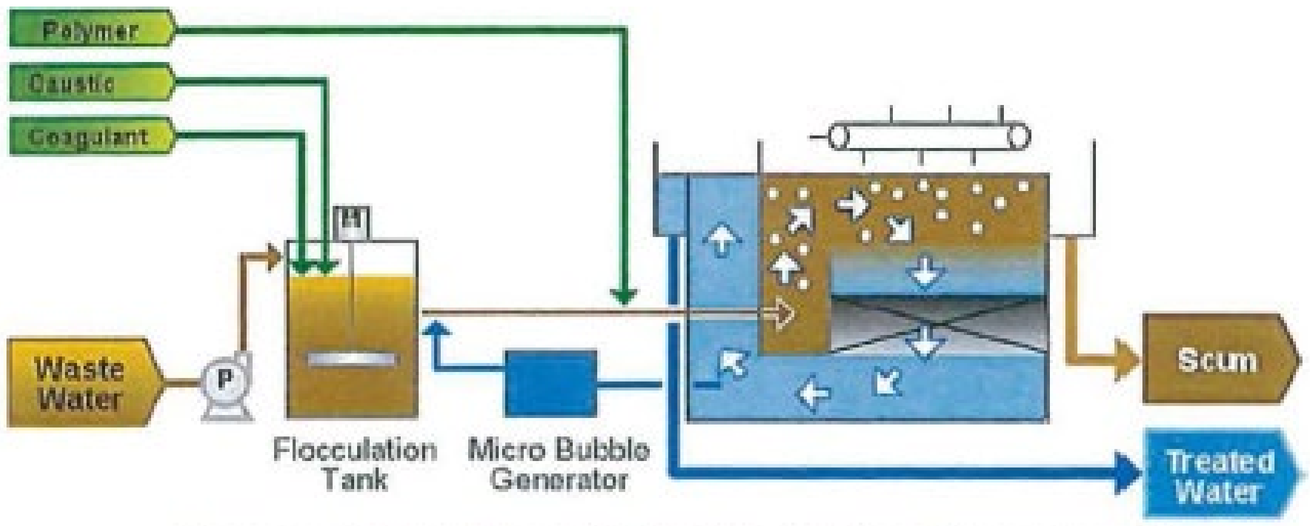
Multi-Staged Fluidized-Bed Activated Carbon Absorption Equipment

Item	Content
1. Process Flow or Diagram	
2. Technology Definition/Specification	The multi-staged fluidized bed allows for continuous feed and extraction of activated carbon. It achieves smaller space and lower cost than the conventional fixed-staged fluidized-bed activated carbon absorption equipment, and provides many advantages including easy operation and maintenance.
3. Field of Application	- Treatment of factory effluent containing organic substances (for chemical, food, iron, paper, medicine, etc.) - Decoloration of colored wastewater - Oil removal from wastewater containing oil (oil refinement wastewater, petrochemistry wastewater, etc.)
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) Environmental Water Quality Standard http://www.env.go.jp/en/water/wq/wp.pdf
5. Benefits	- Lower operating cost : This equipment provides higher usage and contact efficiency of activated carbon to reduce the running cost, compared with the fixed-bed type. - Addresses variation of wastewater quality : By adjusting the feed quantity of activated carbon, the quality of treated water can be kept constant even when the wastewater quality changes. - Saves space and reduces facilities cost : Being different from the fixed-bed type, continuous operation for the entire tower is available and the absorption speed is high, reducing the equipment size and cost. - Backwash is not necessary : the fluidized-bed does not suffer from blocking By contaminating materials contained in the wastewater as seen with the fixed-bed type, eliminating need for backwash.
6. Co-benefits	- Saves labor : Unmanned operation allows for easy operation and management, enables significantly labor saring
7. Japanese Main Supplier	Kobelco Eco-Solutions Co., Ltd
8. Technologies Reference	https://www.kobelco-eco.co.jp/english/product/pdf/industrial_water_treatment/multiactos.pdf

B-4

Waste Water Treatment

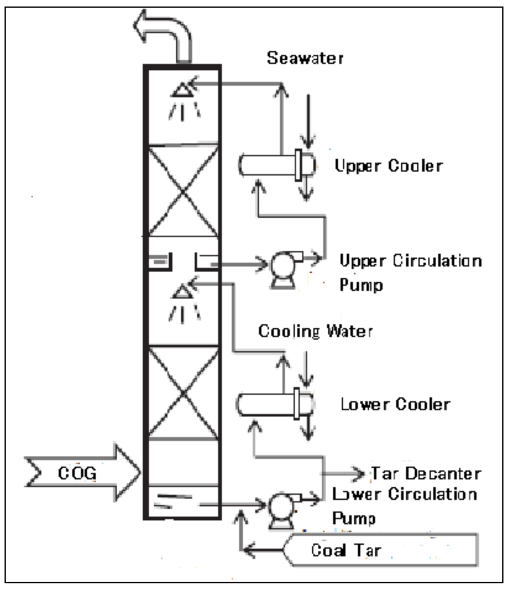
High-Speed Air Flotation System

Item	Content
1. Process Flow or Diagram	 Flow of High-Speed Air Floatation Treatment 
2. Technology Definition/Specification	As a result of the improvement of the structure of the floatation tank, we achieved ten times larger upflow velocity than the conventional system, leading to drastic reduction in installation space required for the unit. It could cut install space by 90%. As specification of the system, easy bubble generation control and fewer components to achieve easy Operations & Maintenance
3. Field of Application	* High Performance * High dissolving efficiency by Micro Bubble Generator * High efficient floatation of oily and suspended matters
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) Environmental Water Quality Standard http://www.env.go.jp/en/water/wq/wp.pdf
5. Benefits	Not Announced
6. Co-benefits	Not Announced
7. Japanese Main Supplier	Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.
8. Technologies Reference	https://power.mhi.com/group/es/products/rainwater/outline

B-5

Waste Water Treatment

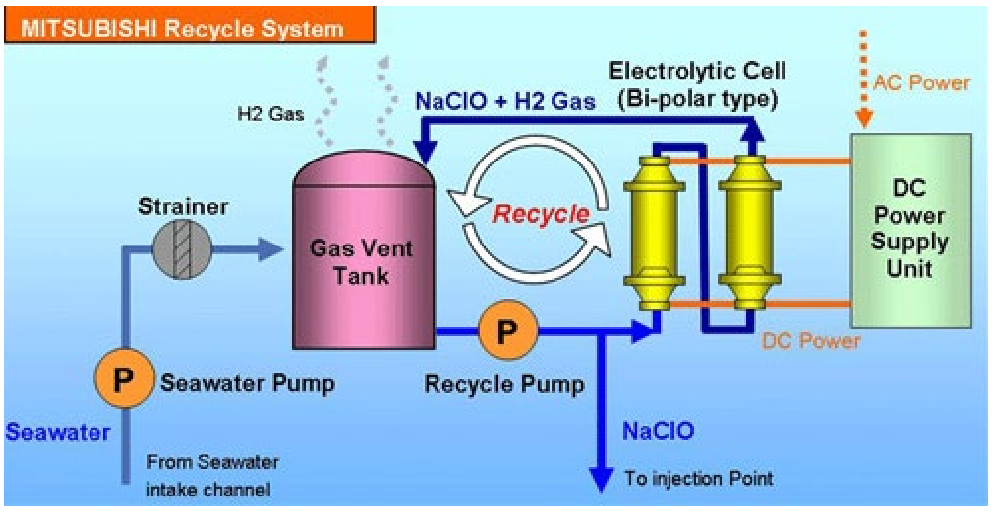
Cooling Tower

Item	Content	
1. Process Flow or Diagram		  COG Cooling System with Double Contact Tower
2. Technology Definition/Specification	Our cooling tower for industry is equipped with the blower module consisting of reliable blower/speed reducer/motor and filling materials of high heat exchange efficiency. We can select the best suited cooling tower from our ample line up suited according to customer's demand of specifications such as quantity of water/quality of water/temperature condition/setting space, and others.	We have various types of COG cooling apparatus, equipped with a direct or an indirect heat exchange system in the cooling tower. The picture shows a cooling tower which has a double contact direct cooling system, avoiding cooler clogging by dissolving the naphthalene precipitate by coal tar in coolant.
3. Field of Application	A cooling tower for industry is applied in the field of every industry such as iron manufacture /chemistry/oil refining/generation/paper manufacture/cement.	A cooling tower of Coke Oven Gas (COG)
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) Environmental Water Quality Standard http://www.env.go.jp/en/water/wq/wp.pdf	
5. Benefits	Not Announced	Not Announced
6. Co-benefits	Not Announced	1) Compact configuration. 2) Economical combination of a direct and an indirect cooling system.
7. Japanese Main Supplier	Kobelco Eco-Solutions Co., Ltd	Nippon Steel Engineering Co., Ltd
8. Technologies Reference	https://www.kobelco-eco.co.jp/english/product/cooling_tower/	https://www.eng.nipponsteel.com/english/whatwedo/steelplants/

B-6

Waste Water Treatment

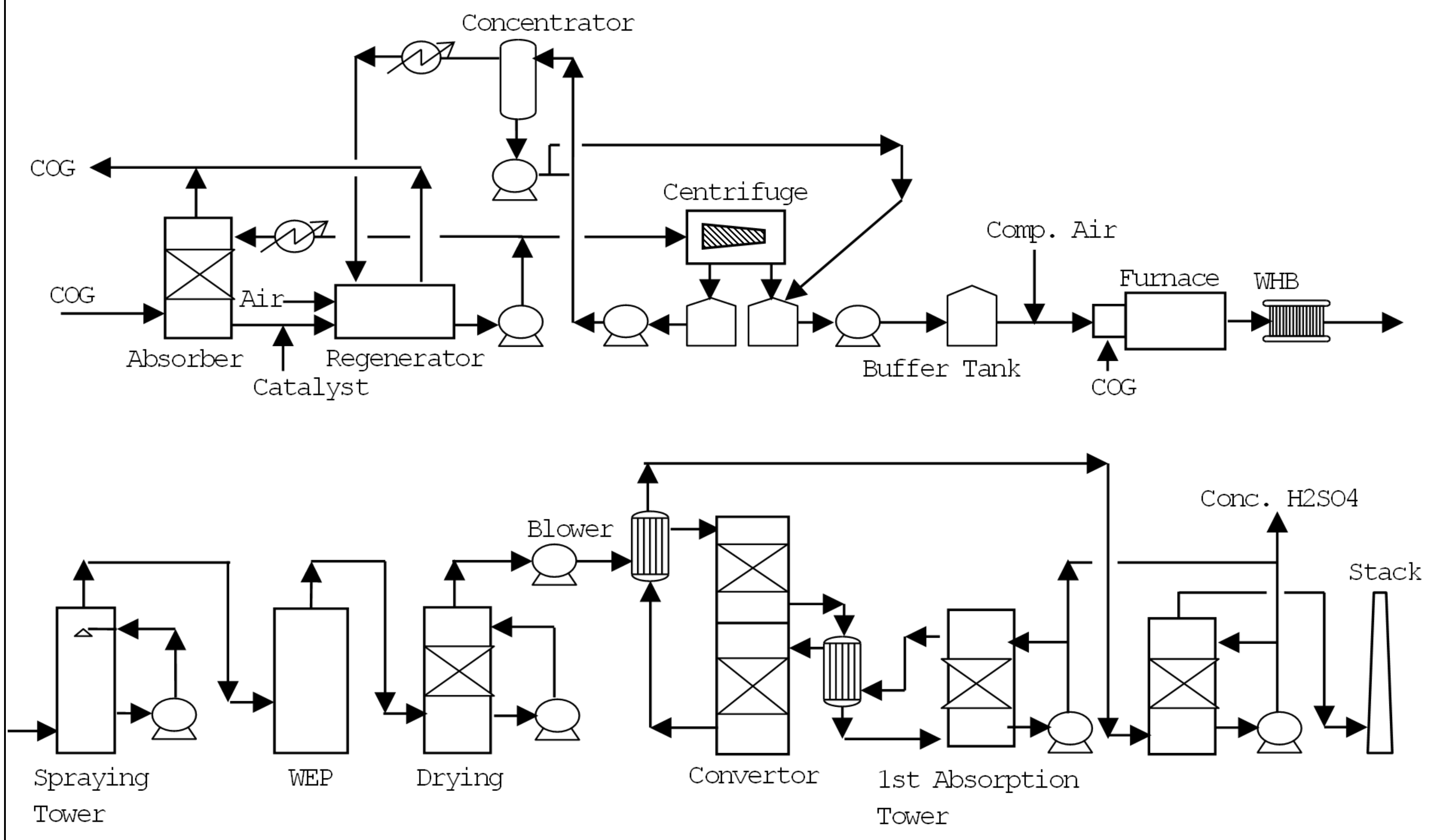
Electrochlorination System

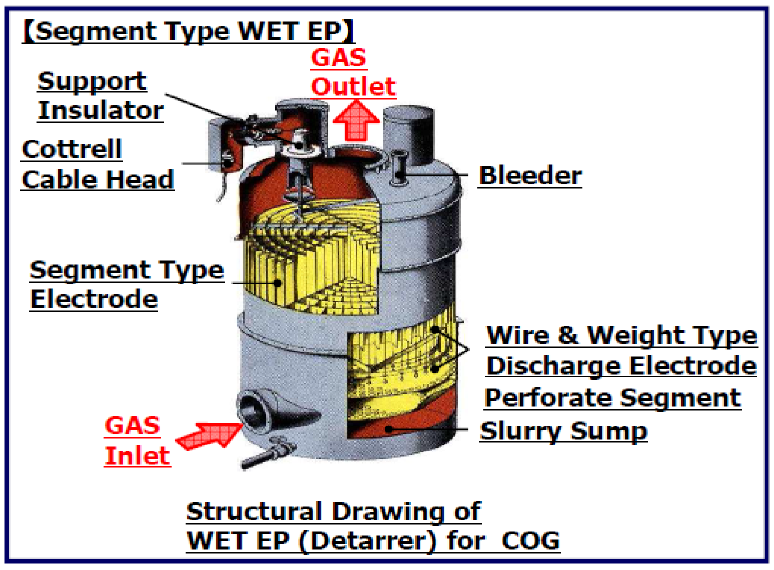
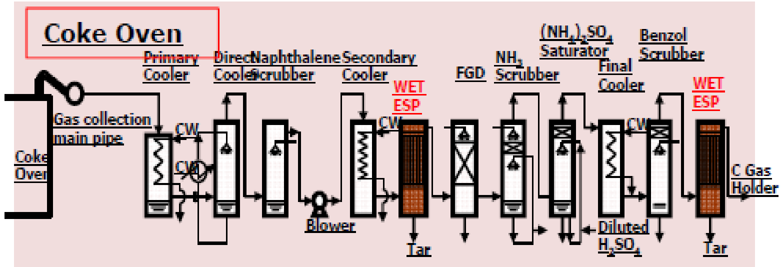
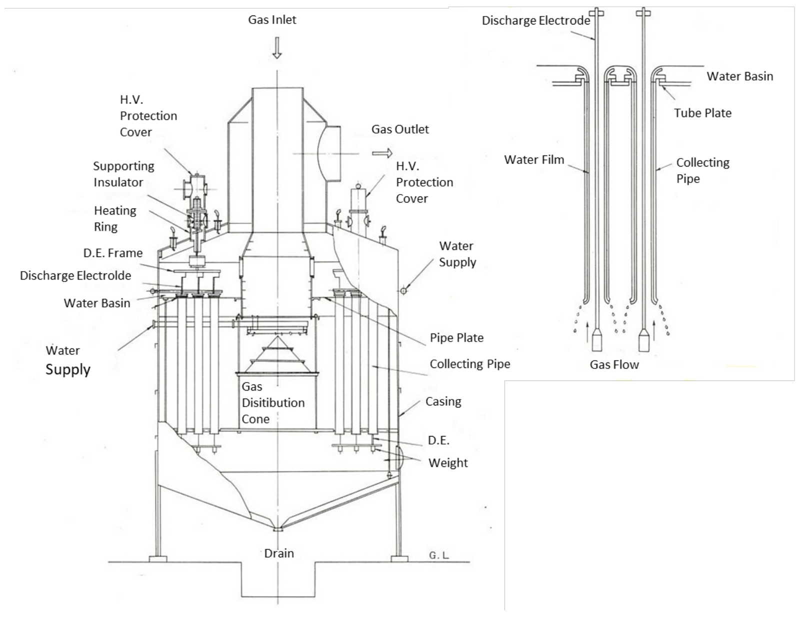
Item	Content
1. Process Flow or Diagram	**Mitsubishi MGPS® (Marine Growth Preventing System), a representative technology of electrochlorination system, has the environmental friendly process.** **Sodium hypochlorite solution produced in the Bi-polar cell unit is transported to the cell unit again with seawater, while some portion of it is discharged into the seawater inlet channel.**   
2. Technology Definition/Specification	**Mitsubishi MGPS® is the best solution for maintaining the efficiency of cooling systems in your plant !** **①Proven Technology** **MITSUBISHI MGPS® has over 50 years experience since 1965.** **②Safety and harmless** **Produced sodium hypochlorite is almost consumed and discharged into the seawater** **③High Durability** **High chlorine generation efficiency achieved for a long time by original highly durable electrode coating.** **④High Availability & Maintainability** **Mitsubishi MGPS® can reduce the frequency of acid cleaning to 1/12.**
3. Field of Application	**Mitsubishi MGPS® can be applied to variouis kinds of plants on the sea!** **Wide capacity for any scales of plants** ●**Iron Mills** ●Coal-fired Thermal Power Plant ●Gas Turbine Combind Cycle Thermal Power Plant ●Nuclear Power Plant ●LNG/LPG Terminals ●Seawater Desalination Plants ●Oil Refinery Plants ●Chemical Plants (Fertilizer, Ammonia, Methanol, etc.) ●Coastal Sewage Treatment Plants ●Offshore Structure (Offshore Oil Platform, etc.)
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) / Ministry of Environment ambient air quality standard http://www.env.go.jp/en/air/aq/aq.html
5. Benefits	･**Reliable adhesion prevention** by electro chrolination technology ･**Stable and improved plant operation rate** by protection of cooling system ･**Reduction of LCC (Life Cycle Cost)** through energy-saving and chemical-saving technologies. Waste liquid treatment costs also can be reduced by over 90%.
6. Co-benefits	･**Eco-Technology for the local environment** ･**Safe Operation for plant operators**
7. Japanese Main Supplier	Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd.
8. Technologies Reference	**Trackrecord : More than 165 Plants all over the world.** https://www.mhiec.co.jp/products/electrolysis/menes/menes_technologie.html

B-7

Reduction of SO_2 from Coke Oven gas by Desulphurization

Reduction of SO_2 from Coke Oven gas by Desulphurization

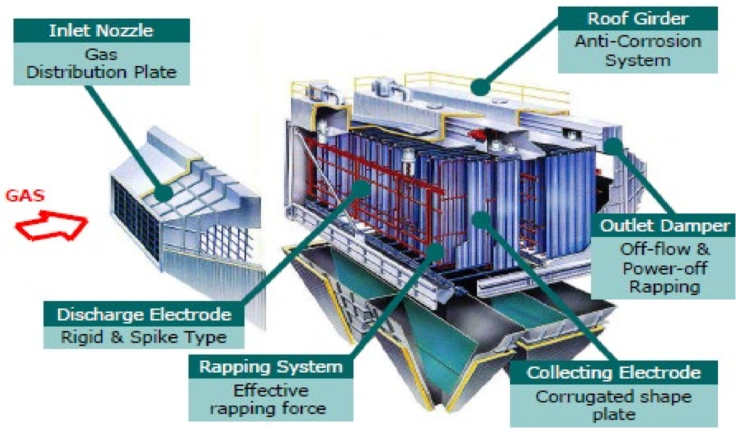
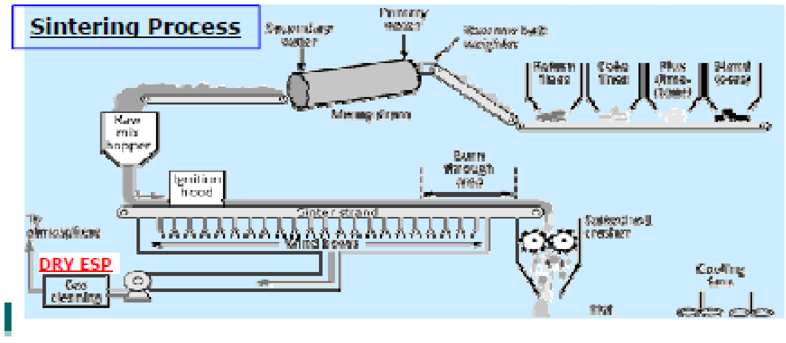
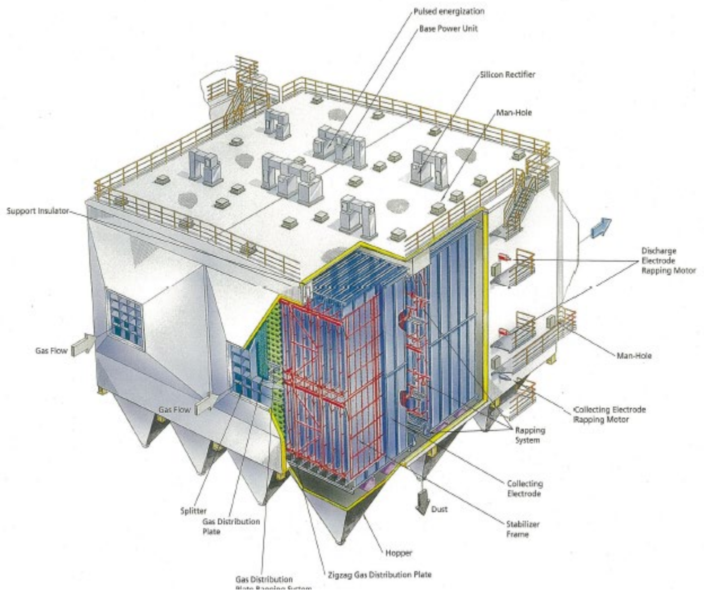
Item	Content
1. Process Flow or Diagram	
2. Technology Definition/Specification	The NNF Process, the latest desulfurization process for coke oven gas which does not produce the contaminated waste water, is able to produce the conc.-H2SO4 from contaminated waste water including elemental sulfur and ammonium salt. This process is at an advantage over the other wet oxidation processes or the absorption/stripping processes in desulfurization efficiency and operating costs, the optimum solution in terms of economy, SO2 emission minimizing & environmental protection.
3. Field of Application	The removal of Hydrogen Sulfate from COG
4. Regulatory and/or administrative frameworks in Japan	Ambient air quality standard http://www.env.go.jp/en/air/aq/aq.html
5. Benefits	Not Announced
6. Co-benefits	The liquid oxidation section, because of exothermic reactions in the reaction tower, does not need to be heated from the outside.
7. Japanese Main Supplier	Nippon Steel Engineering Co., Ltd.
8. Technologies Reference	https://www.eng.nipponsteel.com/english/whatwedo/steelplants/

<table>
<tr><td rowspan="2">B-8</td><td colspan="2">Dust Emissions Control</td></tr>
<tr><td colspan="2">Wet type Electrostatic Precipitator for COG</td></tr>
<tr><th>Item</th><th colspan="2">Content</th></tr>
<tr><td>1. Process Flow or Diagram</td><td>
Structural Drawing of WET EP (Detarrer) for COG
 </td><td> </td></tr>
<tr><td>2. Technology Definition/Specification</td><td colspan="2">Low outlet dust(Tar) concentration < 1mg/Nm3
Wire & Weight Type Discharge Electrode Perforate Segment Sllurry Sump</td></tr>
<tr><td>3. Field of Application</td><td colspan="2">Tar separation from coke oven gas
Stable performance and continuous operation with countermeasures for corrosion, explosive and high pressure gas (1,500mmAq ~ 2,000mmAq)</td></tr>
<tr><td>4. Regulatory and/or administrative frameworks in Japan</td><td colspan="2">(Basic Environment Law)
Environmental Water Quality Standard
http://www.env.go.jp/en/water/wq/wp.pdf</td></tr>
<tr><td>5. Benefits</td><td colspan="2">Not Announced</td></tr>
<tr><td>6. Co-benefits</td><td colspan="2">Not Announced</td></tr>
<tr><td>7. Japanese Main Supplier</td><td>Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.</td><td>Sumitomo Heavy Industries,Ltd.</td></tr>
<tr><td>8. Technologies Reference</td><td></td><td>https://www.shi.co.jp/english/products/environment/electricity/index.html</td></tr>
</table>

B-9

Dust Emissions Control

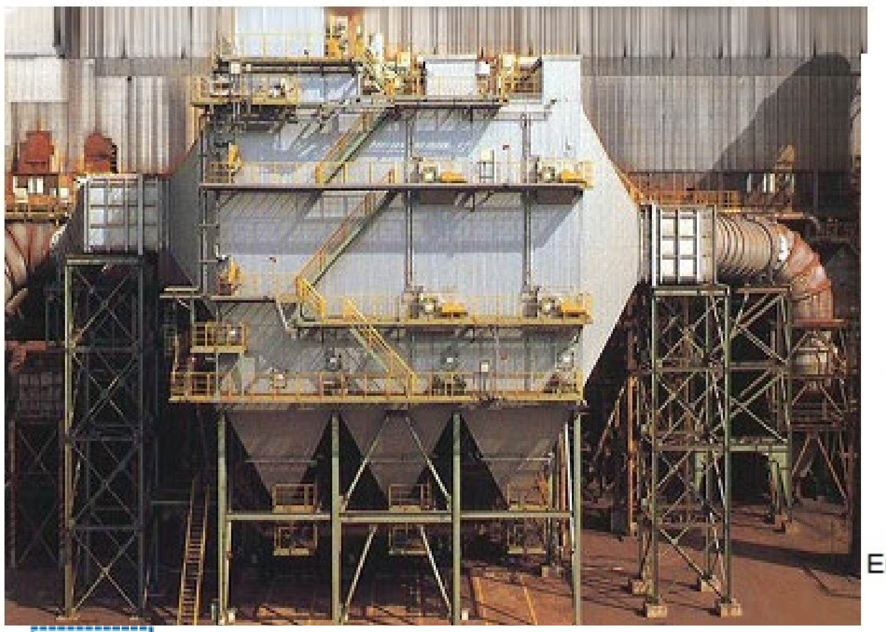
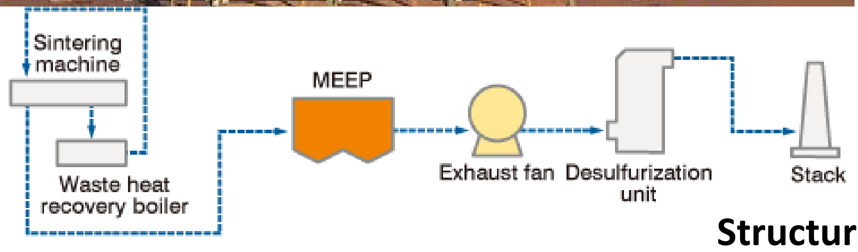
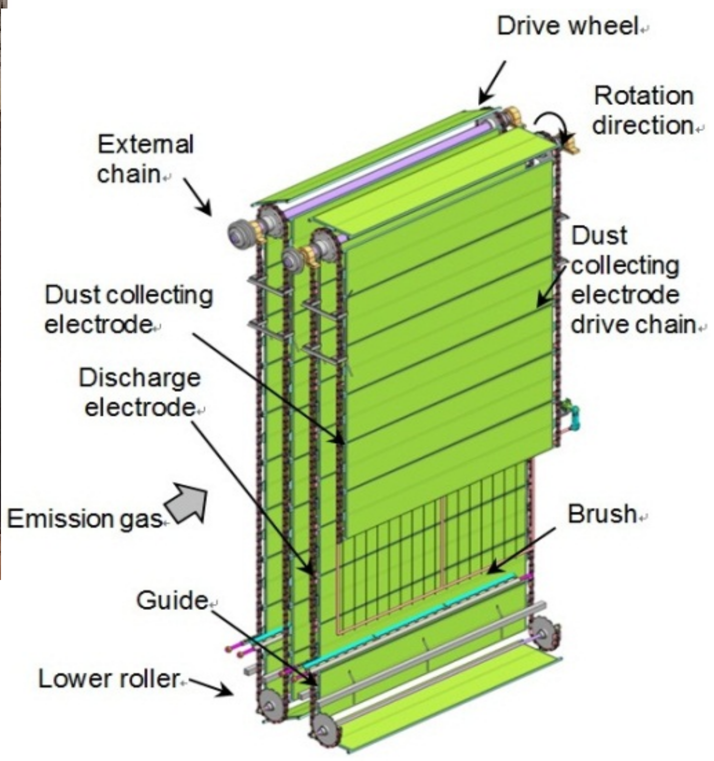
Dry type Electrostatic Precipitator

Item	Content	
1. Process Flow or Diagram	  	
2. Technology Definition/Specification	* The precipitator structure and dimensions have been standarized to actualize the gas flow distribution to be uniform, so that flow distribution test at site fis not needed *Unique lattice-type gas distribution plate, which is configured to prevent dust adhesion and clogging, can be used without rapping *The discharge electrodes of high mechanical strength and superior discharging properties are used according to dust concentration and properties in each section, to ensure optimum energization conditions * Component except for the driving motor are built in, thus no noise is emitted. * Support insulators are protected at all times by seal air and heater, avoiding damage caused by dust sticking or moisture condensation. * Discharge electrodes are extremely strong specially-molded electrodes, short in length and fixed to the support frame (pipe), so as to prevent energization failure due to vibration or breakage due to fatigue.	*The ESP incorporates a three-stage gas distribution system in the splitter in the gas entry section to ensure that the gas is evenly distributed for entry to the energizing chamber. *The discharge electrode provide the excellent discharge characteristics due to the optimum shape, and has good stablity with the strength and rigidity of electrode. The possibility of breakage is minimaized. *The Unique shape collecting electrode, called sigma III, has the cross section strength withstand rapping impact. At the same time it can acheive high rapping efficiency and uniform distribustion of the electrical field. *The Rapping systems feature low rapping reentrainment and high rapping effect to calculate the appropriate rapping force. *Puse enegization system is installed to obatain the significant improvement in the performance of ESP against to the dust which has high electirical resitivity and under the back ionization. *Advanced energizaiton control system can be adopted with individual configuration developed by ourself and latest digital signal process remote control.
3. Field of Application	* Sinter main gas treatment are highly evaluated by customers under strict conditions such as high negative pressure (-1,000～2,500mmAq), high dust resistivity, flammable,corrosive,etc ⇒10～50mg-dust/Nm3	
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) / Ministry of Environment ambient air quality standard http://www.env.go.jp/en/air/aq/aq.htm	
5. Benefits	Not Announced	
6. Co-benefits	Not Announced	
7. Japanese Main Supplier	Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.	Sumitomo Heavy Industries,Ltd.
8. Technologies Reference	https://power.mhi.com/products/aqcs/lineup/dust-collector	https://www.shi.co.jp/english/products/environment/electricity/index.html

B-10

Dust Emissions Control

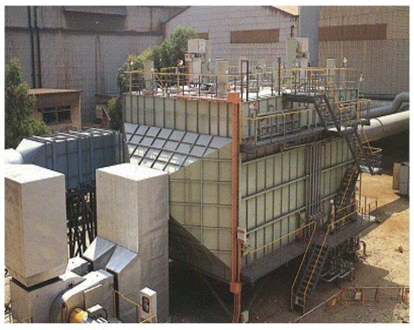
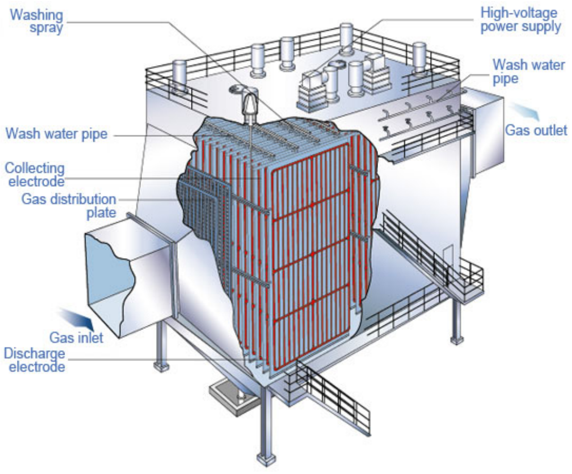
Moving Electrode Electrostatic Precipitator : MEEP

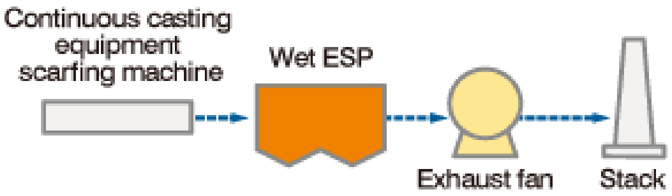
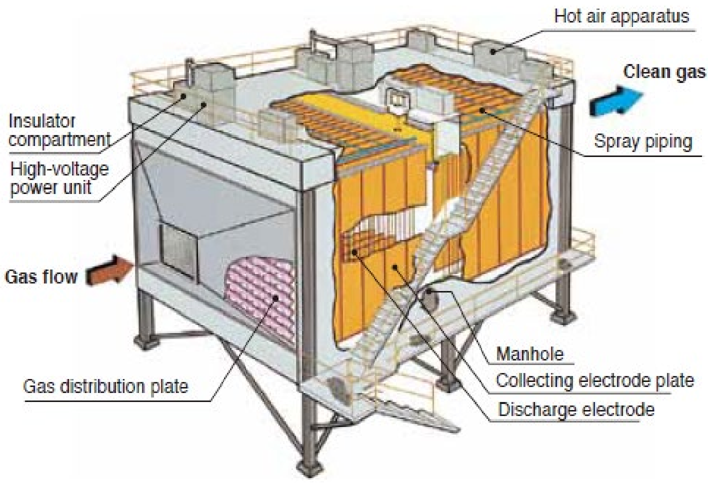
Item	Content
1. Process Flow or Diagram	   **Structural Diagram of Moving Electrode Unit**
2. Technology Definition/Specification	Electrostatic precipitators are devices that collect dust by drawing it to the dust collecting electrode by using a discharge electrode to electrostatically charge the dust in the gas included in the flue emissions. With conventional fixed electrode electrostatic precipitators, the collection plate is hammered at regular intervals to knock off the collected dust. However, it is difficult to sufficiently remove highly adhesive, high resistivity dust from the plate. As a result, the surface of the collecting plate becomes covered by layers of adhered high-resistivity dust. If operation continues under these conditions, high-resistance obstruction and the back corona phenomenon will occur due to the dust covering the collecting plate. The corona current from the discharge electrode will be abated, and the dust deposited on the collecting electrode will cause dielectric breakdown, seriously degrading the dust collection performance. For the moving electrode electrostatic precipitator, a moving electrode mechanism and a new method that removes dust by means of brushes were developed, enabling the efficient collection of high-resistivity dust and a space-saving footprint. * High performance Since high-resistivity dust and ultrafine dust collected on the collecting electrode can be efficiently removed by brushes, dust collection efficiency is high. Also, because dust removal takes place outside of the dust collection area, there is no reentrainment and high performance can be maintained. * Space saving and power saving Since dust collection efficiency is high, the apparatus can be made significantly smaller and power consumption can be reduced, enabling energy-saving operation.
3. Field of Application	Cleaning exhaust gas from sintering machines
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) / Ministry of Environment ambient air quality standard http://www.env.go.jp/en/air/aq/aq.html
5. Benefits	Not Announced
6. Co-benefits	Not Announced
7. Japanese Main Supplier	Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.
8. Technologies Reference	https://power.mhi.com/products/aqcs/lineup/dust-collector

B-11

Dust Emissions Control

Wet type Electrostatic Precipitator for Scarfing Machine and Gas Cutting Machine

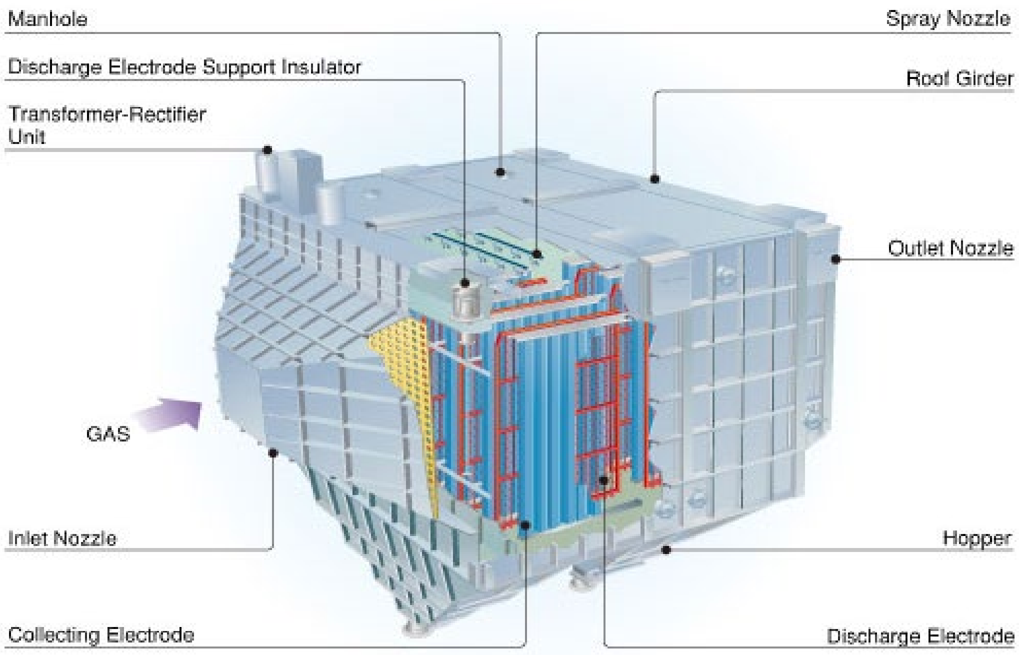
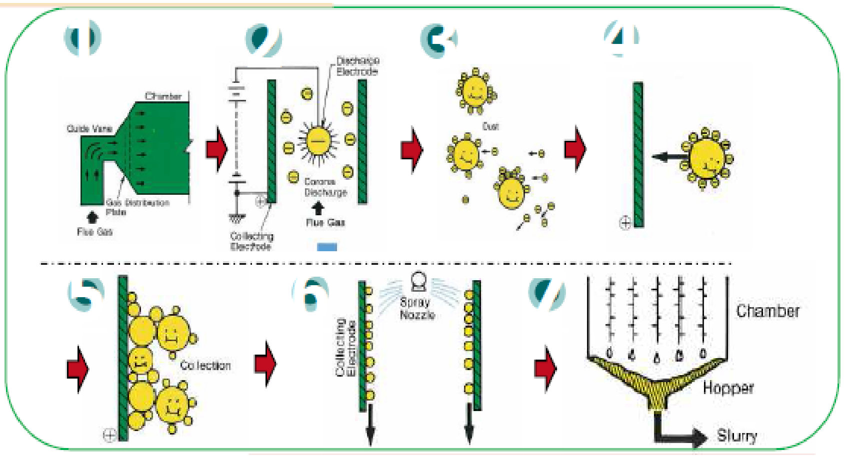
<table>
<tr><th>Item</th><th colspan="2">Content</th></tr>
<tr><td>1. Process Flow or Diagram</td><td>



</td><td>
</td></tr>
<tr><td>2. Technology Definition/Specification</td><td>Dust and mist, including submicron particulate, are collected on collecting plates and then washed away by water sprays. Offering minimal water consumption, the Hitachi Plant Construction's wet ESP is designed with the configuration that is optimal for the customer's specific system. This enables high performance - reducing the outlet dust concentration to less than 1 mg/m3 - from a compact wet ESP capable of handling high gas velocity.
In addition, this system has following specification;
(1) Reduced outlet dust concentration
(2) Compact configuration
(3) Reduced water consumption for washing the collecting electrodes and effectiveness with high gas velocity
(4) Reduced use of industrial water
(5) Total water treatment planning</td><td>Dust and mist, including submicron particulate, are collected on collecting plates and then washed away by water sprays.
The Wet Electrostatic Precipitator(WESP), which was developed by Sumitomo Heavy Industries, Ltd.(SHI), has following specification;
(1) Excellent dust removal performance.
(2) Wide range of applications under such the corrosive and explosive conditions
(3) Less breakdowns considering the staructure with disconneciting of discharge electrode and breakage of insulators
(4) Low running cost regarding the optimum energization control system and water consumption
(5) Space-saving, Compact considering the properties of the waste flue gas and the lack of reentrainment.</td></tr>
<tr><td>3. Field of Application</td><td colspan="2">Cleaning exhaust gas from scarfing machines, Wet type ESP for gas cutting machine</td></tr>
<tr><td>4. Regulatory and/or administrative frameworks in Japan</td><td colspan="2">(Basic Environment Law) / Ministry of Environment ambient air quality standard
http://www.env.go.jp/en/air/aq/aq.html</td></tr>
<tr><td>5. Benefits</td><td colspan="2">Not Announced</td></tr>
<tr><td>6. Co-benefits</td><td colspan="2">Not Announced</td></tr>
<tr><td>7. Japanese Main Supplier</td><td>Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.</td><td>Sumitomo Heavy Industries,Ltd.</td></tr>
<tr><td>8. Technologies Reference</td><td>https://power.mhi.com/products/aqcs/lineup/dust-collector</td><td>https://www.shi.co.jp/english/products/environment/electricity/index.html</td></tr>
</table>

B-12

Dust Emissions Control

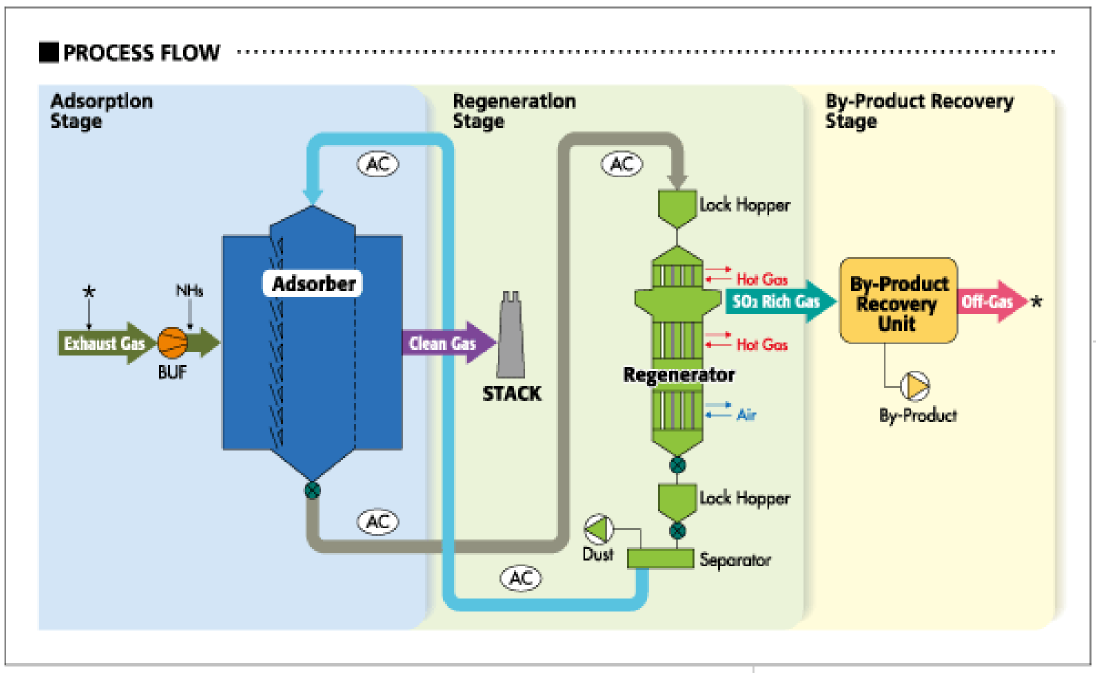
Wet type Electrostatic Precipitator for By-Produced Gas Turbine

Item	Content
1. Process Flow or Diagram	  
2. Technology Definition/Specification	* Using water in removing the collected dust, the wet EP can achieve high dust removal efficiency (less than over equal to1mg/m3N at wet type EP outlet is also possible) without being affected by the high or low electrical resistivity of dust. * Using an excellent atomization electrode washing nozzle, the discharge electrodes and collecting electrodes can be washed * In case significant corrosion is evident due to the gas property or quality of water, corrosion-resistant design such as stainless steel, FRP, and flake lining is being considered.
3. Field of Application	* Wet type EP for by-produced gas turbine for power generation remove solid particulate matters contained in the fuel, actualizing ultralow concentration in order to protect compressors for gas turbines. * Effective for SO3, PM2.5, and Heavy metals
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) / Ministry of Environment ambient air quality standard http://www.env.go.jp/en/air/aq/aq.html
5. Benefits	Not Announced
6. Co-benefits	Not Announced
7. Japanese Main Supplier	Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.
8. Technologies Reference	https://power.mhi.com/products/aqcs/lineup/dust-collector

B-13

Exhaust Gas Treatment through Denitrification, Desulfurization

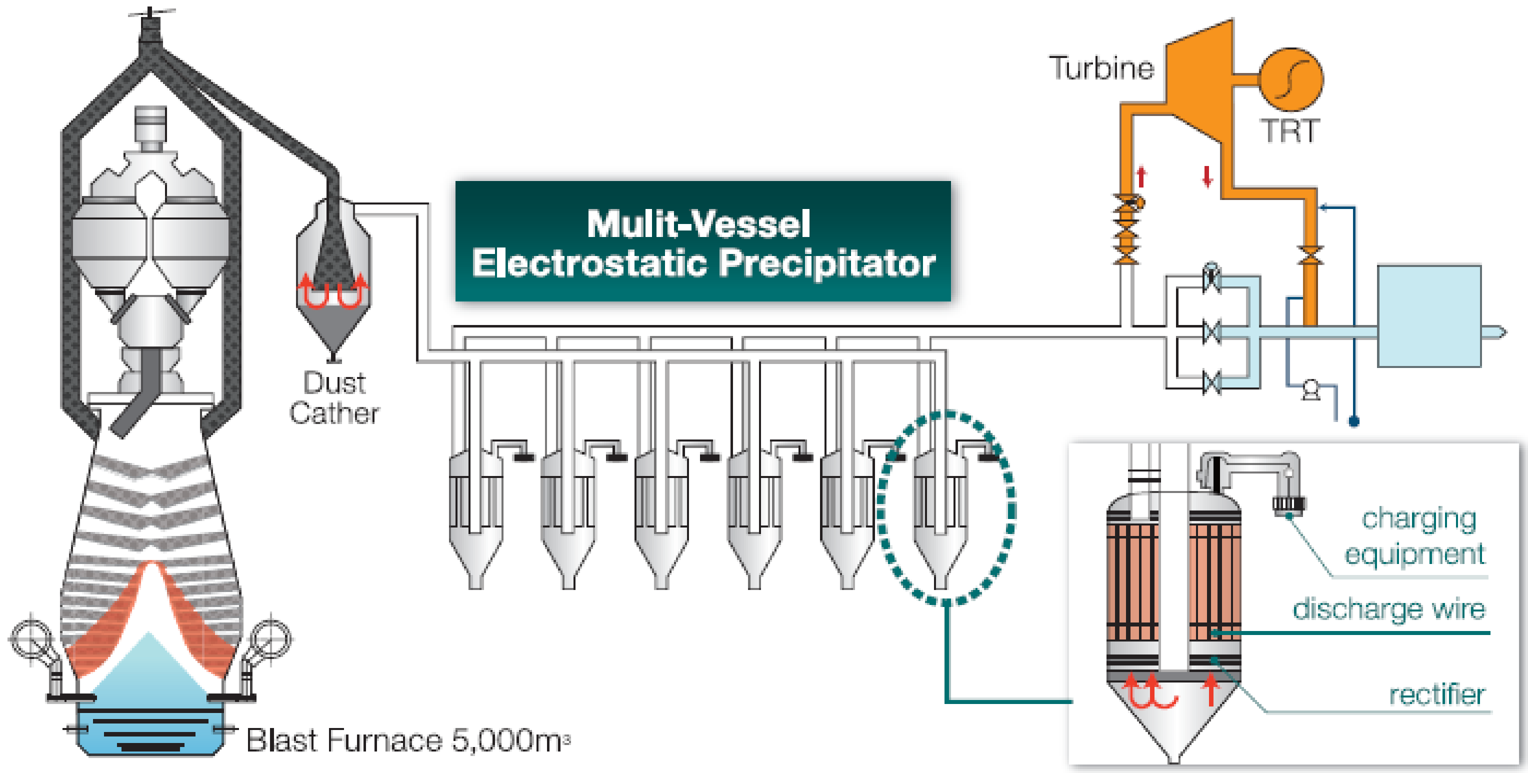
Dry Activated Coke Exhaust Gas Treatment Facilities

Item	Content
1. Process Flow or Diagram	  
2. Technology Definition/Specification	The activated coke in the moving bed moves slowly in a vertical direction (top to bottom). As it moves it comes into contact with the exhaust gases that flow in a horizontal direction, eliminating pollutants. This method is referred to as the cross flow moving bed method and also provides a dust collecting function. This method is capable of eliminating DXNs and Heavy Metals such as Hg in exhaust gases.
3. Field of Application	* Sintering Machines in steel plants * Pulverixed coal fired power plants * Incinerater
4. Regulatory and/or administrative frameworks in Japan	(Basic Environment Law) / Ministry of Environment ambient air quality standard http://www.env.go.jp/en/air/aq/aq.html
5. Benefits	Not Announced
6. Co-benefits	- Various harmful components included in exhaust gases can be eliminated - No changes to the temperature of exhaust gases - Small amount of service water used - Byproducts (sulfuric acid, gypsum, etc.) can be selected to suit the installation location - Small amount of waste materials generated
7. Japanese Main Supplier	J-POWER EnTech, Inc. Nippon Steel Engineering Co., Ltd.
8. Technologies Reference	

B-14

Blast Furnace Gas and Cast House Dedusting

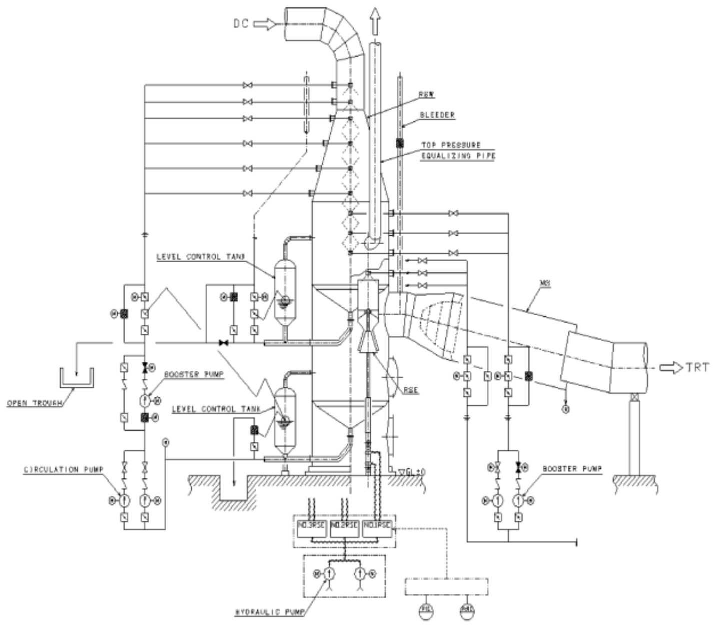
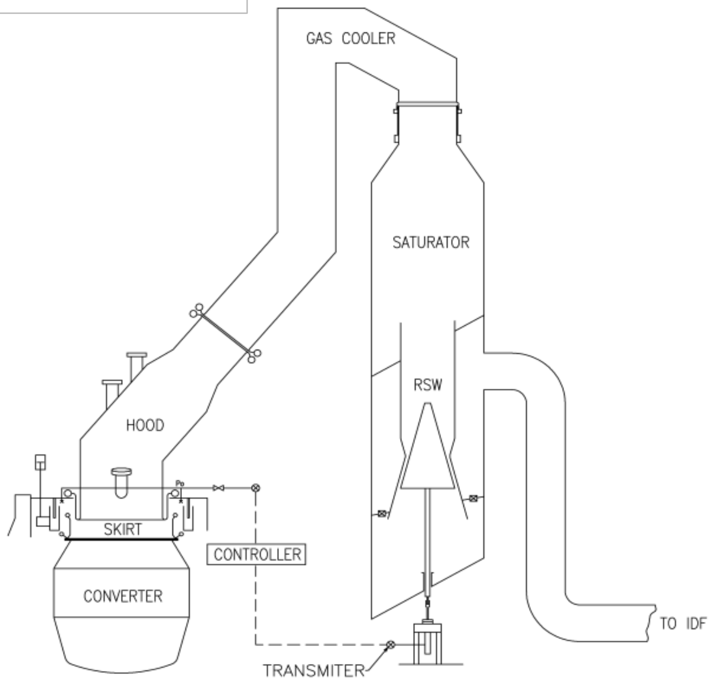
Multi-Vessel Electrostatic Precipitator

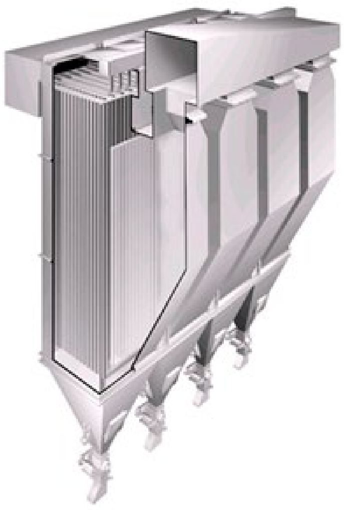
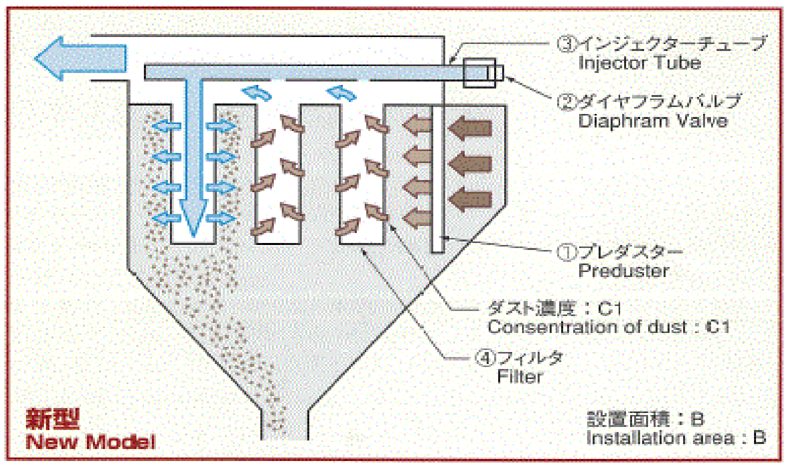
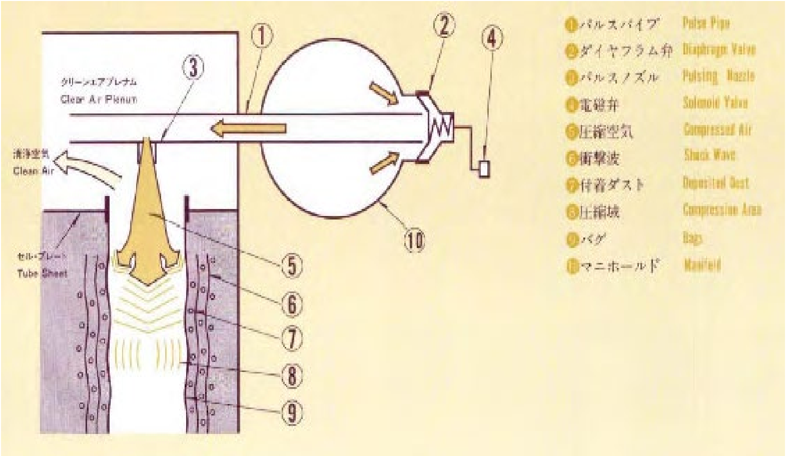
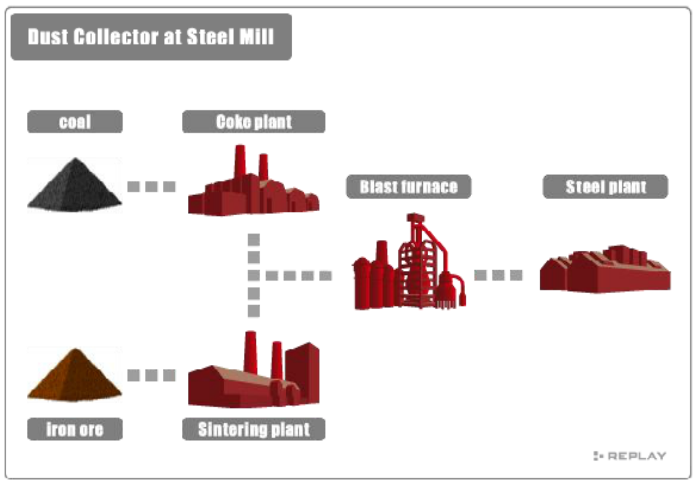
Item	Content
1. Process Flow or Diagram	
2. Technology Definition/Specification	Multi-vessel electrostatic precipitator (MVEP), instead of the existing 2-stage venturi scrubber, is arranged in the system, and dust and water drops are removed by electric energy in MVEP located in the gas turnover/rising section in each vessel, which generates clean gas. Since the temperature drop and pressure loss is reduced as compared to 2-stage venturi scrubber, TRT power generation is increased by 30%, with realizing the dust content at the outlet of the system of 5 mg/Nm3 or lower. And, since there is no temperature limitations as compared to bag filter, this system has excellent durability at high temperature gas inlet by operation fluctuations.
3. Field of Application	Blast Furnace
4. Regulatory and/or administrative frameworks in Japan	Strategic Energy Plan Act on Promotion of Global Warming Countermeasures
5. Benefits	- TRT power generation is 10% larger than bag filter type, and 30% larger than wet type. - Conpact, saving space system compared to bag filter type - Achieved exellent dust collection performance
6. Co-benefits	Lower water consumption compared with wet-type
7. Japanese Main Supplier	Nippon Steel Engineering Co., Ltd.
8. Technologies Reference	PMD NEWS 2013(Published: May.2013) https://www.eng.nipponsteel.com/english/whatwedo/steelplants/

B-15

Blast Furnace Gas and Cast House Dedusting

Ring Slit Washer (RSW) Wet Gas Scrubber

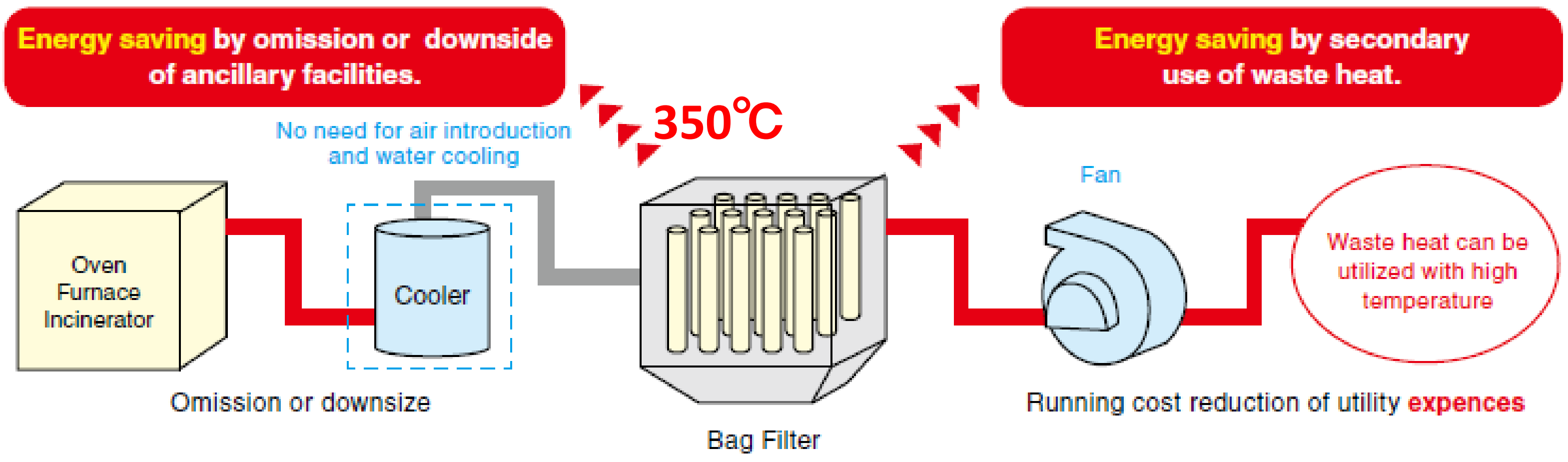
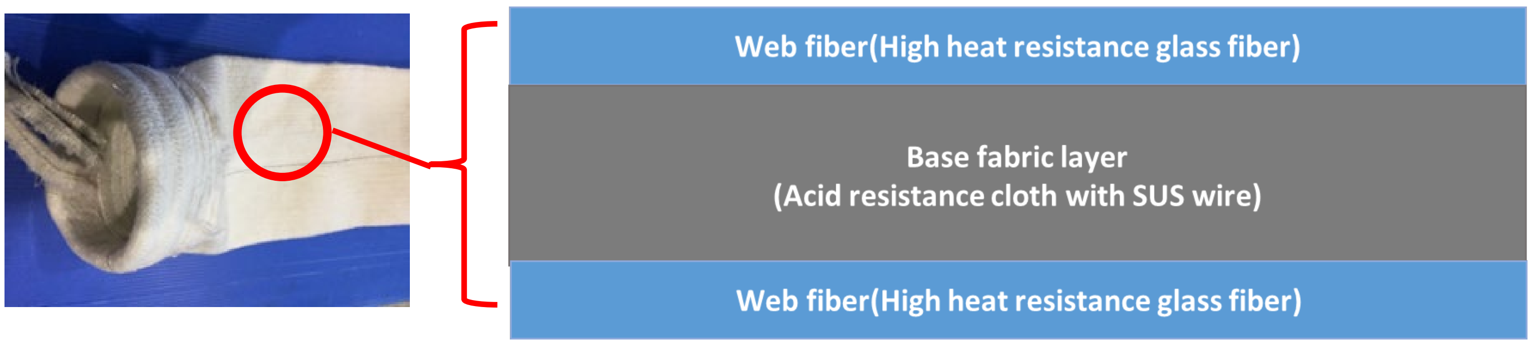
Item	Content
1. Process Flow or Diagram	BFG  CONVERTER GAS 
2. Technology Definition/Specification	The RSW jointly contains an auxiliary spray tower-type scrubber in its upper part and a variable throat-type venturi scrubber called RSE in its lower part. When this system is applied to the blast furnace, an axis flow mist separator is installed in the downstream to separate air and liquid and realizes the dust content at the outlet of the system of 5 mg/Nm3 or lower. When this system is applied to the converter, gas from the gas cooler is cooled down again to 70 deg C by the saturator and 99.9% of dust, which is contained high concentrated in the gas, is removed at dust collector(RSE) In addition, this system has following specification; * Compact, space-saving system. * Achieved excellent dust collection performance with its low load differential pressure and liquid-gas ratio. * When this system applied to BF, the load differential pressure is 30 kPa, and the dust content at the outlet of the RSW is 5 mg/Nm3 or lower . * When this system applied Converter, the load differential pressure is 15 - 20 kPa, and the dust content at the outlet of the RSW is 20 mg/Nm3 or lower. * Realized excellent blast furnace top pressure control performance. * Realized excellent converter throat pressure control performance, results high gas recovery efficiency(70-90%)
3. Field of Application	The Ring Slit Washer (RSW) wet gas scrubber is used widely with various dust collection devices, including its use for cleaning the gas emitted by blast and converter furnaces.
4. Regulatory and/or administrative frameworks in Japan	Strategic Energy Plan Act on Promotion of Global Warming Countermeasures
5. Benefits	Not Announced
6. Co-benefits	Not Announced
7. Japanese Main Supplier	JP Steel Plantech Co. (SPCO)
8. Technologies Reference	http://steelplantech.com/product/rsw/

<table>
<tr><td rowspan="2">B-16</td><td colspan="2">Blast Furnace Gas and Cast House Dedusting</td></tr>
<tr><td colspan="2">Pulse type Bag Filter</td></tr>
<tr><th>Item</th><th colspan="2">Content</th></tr>
<tr><td>1. Process Flow or Diagram</td><td>
 </td><td>
 </td></tr>
<tr><td>2. Technology Definition/Specification</td><td colspan="2">When the diaphragm valve is opened, compressed air is discharged through the pulsing nozzle. It creates shock wave which break the deposition of dust cake.
Reduction in the number of parts and components, such as the filtering cloth, leads to a reduced number of replacement parts and therefore the costs involved in work for exchanging parts and components are reduced.
Also, the adoption of a high-speed filtration and long length filtering cloth achieved space saving.</td></tr>
<tr><td>3. Field of Application</td><td colspan="2">* Coke Plant
Coal charging car
Coke guide
Pusher
Flue gases from coke oven
* Sintering Plant
Sinter cooler
* Blast Furnace
Coal Pulverization for BF Injection
* House dedusting
 </td></tr>
<tr><td>4. Regulatory and/or administrative frameworks in Japan</td><td colspan="2">(Basic Environment Law) / Ministry of Environment
ambient air quality standard
http://www.env.go.jp/en/air/aq/aq.html</td></tr>
<tr><td>5. Benefits</td><td colspan="2">Not Announced</td></tr>
<tr><td>6. Co-benefits</td><td colspan="2">Not Announced</td></tr>
<tr><td>7. Japanese Main Supplier</td><td>Nihon Spindle Manufacturing, Sumitomo Heavy Industries, Ltd</td><td>Shinwa Corporation</td></tr>
<tr><td>8. Technologies Reference</td><td>http://www.spindle.co.jp/product/dust.html
http://www.shi.co.jp/english/products/environment/dust/index.html</td><td>https://www.shinwatec.co.jp/products/air_pollution_control_systems/
https://www.shinwatec.co.jp/en/pollution/</td></tr>
</table>

B-17

Blast Furnace Gas and Cast House Dedusting

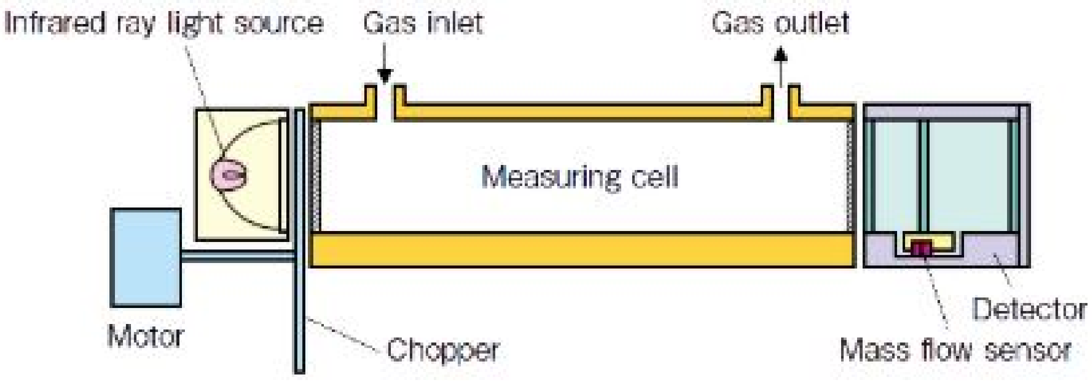
High temperature filter bag(nanolof HT)

Item	Content
1. Process Flow or Diagram	**INTRODUCTION EFFECTS**  **Using nanolof HT, it is NOT necessary to lower the gas temperature below 200℃ by cooling equipment before dedusting system.** **(Normal filter bags can be used only at200℃ for regular use, and up to 230℃ for a moment.)** 
2. Technology Definition/Specification	･High temperature resistance up to Max 350℃ ･Non-flammable material (High resistance for sparks) ･High strength (approximately 30% stronger than regular filter bag) ･Easy handling and installation compared to ceramic forming filter bag.
3. Field of Application	Waste gas treatment facilities relating to incinerator, steel factory, power plant, waste treatment plant and chemical plant.
4. Regulatory and/or administrative frameworks in Japan	
5. Benefits	Bag filter can be operated at high temperature condition(300℃ or more) and less damage from sparks. Energy and utility cost saving can be achieved due to omission or downside of existing cooling facility.
6. Co-benefits	More waste heat recovery can be achieved after dedusting.
7. Japanese Main Supplier	Shinwa corporation
8. Technologies Reference	

B-18

General Technology

Gas Analyzer

Item	Content
1. Process Flow or Diagram	 
2. Technology Definition/Specification	Gas Analyzer is capable of measuring the NO, SO2, CO2, CO, CH4, N2O and O2 components in sample gas by detecting the amount of infrared rays absorbed by a Measuring cell, with Mass flow sensor. There are various types of gas analyzers for each applications and it is used to support environmental preservation and control atmospheric pollution as well as monitor the atmosphere to help maintain a cleaner natural environment. Fuji Electric produce the whole equipment including the sensor, which is an important part of Gas Analyzer.
3. Field of Application	Blast furnace, Converter funacer, Heat treatment furnace, Sintering (pallet equipment), Coke oven (CDQ)
4. Regulatory and/or administrative frameworks in Japan	(The Basic Environment Law) / Ministry of Environment Environmental Quality Standards http://www.env.go.jp/en/air/aq/aq.html
5. Benefits	Quantitative grasp of substances of atmosphere that cause global warming
6. Co-benefits	Balancing economic activities and environmental conservation by a basic data provided by Gas Analyzer
7. Japanese Main Supplier	Major electric equipment suppliers
8. Technologies Reference	https://www.fujielectric.com/products/instruments/products/anlz_gas/top.html

Contact Points of Suppliers

Company	Energy-Saving Technologies	Environmental Protection Technologies	Contact Points
Chugai Ro Co., Ltd.	A-12: Low NOx regenerative burner system for ladle preheating A-15: Process control for reheating furnace A-16: Regenerative Burner Total system for reheating furnace A-17: High temperature recuperator for reheating furnace A-18: Fiber block for insulation of reheating furnace A-20: Oxygen enrichment for combustion air		3-6-1 Hiranomachi, Chuo-ku, Osaka 541-0046, Japan TEL:+81-6-6221-1251 FAX:+81-6-6221-1411 https://chugai.co.jp/en/
Daido Steel Co., Ltd.	A-21: Highly efficient combustion system for radiant tube burner		1-10, Higashisakura 1-chome, Higashi-ku, Nagoya, Aichi, 461-8581, Japan TEL:+81-52-963-7501 FAX: +81-52-963-4386 https://www.daido.co.jp/en/index.html
Fuji Electric CO., LTD.	A-23: Energy Monitoring and Management Systems	B-18: Gas Analyzer	Gate City Ohsaki, East Tower, 11-2, Osaki 1-chome, Shinagawa-ku, Tokyo 141-0032, Japan https://www.fujielectric.com/contact/?ui_medium=gl_glnavi
JP Steel Plantech Co.	A-1: Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat) A-2: Sinter Plant Heat Recovery (Power Generation from Sinter Cooler Waste Heat) A-3: High Efficient (COG) Burner in Ignition Furnace for Sinter Plant A-4: Coke Dry Quenching (CDQ) A-8: Pulverized Coal Injection (PCI) System A-11: Converter Gas Recovery Device A-13: Converter Gas Sensible Heat Recovery Device A-25: Management of Compressed Air Delivery Pressure Optimization	B-15: Ring Slit Washer (RSW) Wet Gas Scrubber	Kaneko 2nd Building 4-9F 2-6-23 Shin-yokohama, Kohoku-ku, Yokohama 222-0033 JAPAN TEL:+81-45-471-3911 Fax:+81-45-471-4002 https://steelplantech.com/en/
J-POWER EnTech, Inc.		B-13: Dry Activated Coke Exhaust Gas Treatment Facilities	Daiwa NishiShimbashi Building (4F), 3-2-1, Nishi-shinbashi, Minato-ku, Tokyo, 105-0003 Japan TEL:+81-3-3434-7081 FAX:+81-3-3434-7086 Email:mail-box@jp-entech.co.jp https://www.jp-entech.co.jp/en/
Kobe Steel, Ltd.	A-26: Power Recovery by Installation of Steam Turbine in Steam Pressure Reducing Line		ON Building, 9-12, Kita-Shinagawa 5-chome, Shinagawa-ku, Tokyo, 141-8688, Japan TEL:+81-3-5739-6000 FAX:+81-3-5739-6903 http://www.kobelco.co.jp/english/machinery/inquiry/
Kobelco Eco-Solutions Co., Ltd		B-2: High-speed filtration Equipment B-3: Multi-Staged Fluidized-Bed Activated Carbon Absorption Equipment B-5: Cooling Tower	4-78, 1-chome, Wakinohama-cho, Chuo-ku, Kobe, 651-0072, Japan TEL:+81-78-232-8018 FAX:+81-78-232-8051 https://www.kobelco-eco.co.jp/english/
Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd.		B-6: Electro Chlorination System(MGPS)	(Mitsubishi Group) MITSUBISHI HEAVY INDUSTRIES. LTD. 2-3,Marunouchi 3 Chome, Chiyoda-ku, TOKYO 100-8332 JAPAN TEL: +81-3-6275-6199 FAX: +81-3-6275-6474 https://www.mhi.com/
Mitsubishi Heavy Industries Power Environmental Solutions, Ltd.		B-1: High-Speed Coagulating Sedimentation Equipment B-4: High-Speed Air Floatation System B-8: Wet type Electrostatic Precipitator B-9: Dry type Electrostatic Precipitator B-10: Moving Electrode Electrostatic Precipitator(MEEP) B-11: Wet type Electrostatic precipitator for Scarfing Machine and Gas Cutting Machine B-12: Wet type Electrostatic Precipitator for By-Produced Gas Turbine	NISSEKI YOKOHAMA Bldg. 1-8, Sakuragicho 1-Chome Naka-Ku, Yokohama 231-0062, Japan TEL: +81-(0)45-232-4948 FAX: +81-(0)45-307-3400 URL: https://power.mhi.com/jp/group/es/
Mitsui E&S Machinery Co., Ltd.	A-6: Top Pressure Recovery Turbine (TRT)		1-1 Tama 3-chome, Tamano, Okayama, JAPAN Sales Gr. Plant Machinery Service Dept. Technoservice Div. TEL: +81-863-23-2586 https://www.mes.co.jp/machinery/english/
Mitsui E&S Power Systems Inc.	A-19: Induction type billet heater for direct rolling		MESPS Tokyo Office: TEL:+81-3-6806-1075 FAX:+81-3-5294-1121 https://www.mesps.co.jp/contact/index.html

Company	Energy-Saving Technologies	Environmental Protection Technologies	Contact Points
Nihon Spindle Manufacturing Co., Ltd.		B-16: Pulse type Bag Filter	Sumitomo Fudosan Ueno Building No. 5, 1-10-14 Kita-Ueno Taito-ku, Tokyo 110-0014 TEL: +81-3-5246-5610 http://www.spindle.co.jp/en/index.html
Nippon Furnace CO., LTD	A-12: Low NOx regenerative burner system for ladle preheating A-16: Regenerative Burner Total system for reheating furnace A-20: Oxygen enrichment for combustion air		2-1-53, Shitte, Tsurumi-ku, Yokohama City, Kanagawa Prefecture, 230-8666 Japan TEL:+81-45-575-8111 FAX:+81-45-575-8046 Email:webmaster@furnace.co.jp http://www.furnace.co.jp/en.html
Nippon Steel Engineering Co., Ltd.	A-4: Coke Dry Quenching (CDQ) A-5: Coal Moisture Control (CMC) A-6: Top Pressure Recovery Turbine (TRT) A-7: Multi-Vessel Electrostatic Precipitator A-8: Pulverized Coal Injection (PCI) System A-9: Hot Stove Waste Heat Recovery A-10: Top Combustion type Hot Stove with Metallic Burners A-11: Converter Gas Recovery Device A-13: Converter Gas Sensible Heat Recovery Device A-14: Rotary Hearth Furnace Dust Recycling System A-16: Regenerative Burner Total system for reheating furnace	B-5: Cooling Tower B-7: Reduction of SO2 from Coke Oven gas by Desulphurization B-13: Dry Activated Coke Exhaust Gas Treatment Facilities B-14: Multi-vessel Electrostatic Precipitator	Osaki Center Building, 1-5-1 Osaki, Shinagawa-ku, Tokyo 141-8604 Japan TEL: +81-3-6665-2000 https://www.eng.nipponsteel.com/english/
Paul Wurth IHI Co., Ltd.	A-4: Coke Dry Quenching (CDQ)		Toyosu Center Bldg. 9F, 3-3 Toyosu 3-chome, Koto-ku, Tokyo 135-6009 Japan TEL:+81-3-6630-4786 FAX:+81-3-3536-4014 Email:contact@ihi-pw.jp https://www.ihi.co.jp/ihipw/en/index.html
Rozai Kogyo Kaisha Ltd.	A-15: Process control for reheating furnace A-16: Regenerative Burner Total system for reheating furnace A-17: High temperature recuperator for reheating furnace A-18: Fiber block for insulation of reheating furnace A-20: Oxygen enrichment for combustion air		2-14, Minamihorie 1-chome, Nishiku, Osaka, Japan 550-0015 TEL:+81-6-6534-3609 Fax:+81-6-6534-3602 http://www.rozai.co.jp/en/company/index.html
Shinwa Corporation		B-16: Pulse type Bag Filter B-17: High temperature filter bag	Harmony Tower, 1-32-2 Honmachi, Nakano- ku, Tokyo 164-0012 JAPAN Email:info@shinwatec.co.jp https://www.shinwatec.co.jp/en/
Sumitomo Heavy Industries, Ltd.		B-8: Wet type Electrostatic Precipitator B-9: Dry type Electrostatic Precipitator B-11: Wet type Electrostatic precipitator for Scarfing Machine and Gas Cutting Machine	ThinkPark Tower, 1-1 Osaki 2-chome, Shinagawa-ku, Tokyo 141-6025, Japan http://www.shi.co.jp/english/contact/index.html
Tsukishima Kikai CO., LTD.	A-5: Coal Moisture Control (CMC)		3-5-1, Harumi, Chuo-ku, Tokyo 104-0053 (Head Office) TEL:+81-3-5560-6531 FAX:+81-3-5560-6596 (Industrial Sales Dept.) TEL:+81-3-5560-6535 FAX: +81-3-3536-0575 https://www.tsk-g.co.jp/en/