INDIA
Technologies Customized List

&

Technologies One by One Sheets

2022 version Part 2: EAF (v.4.2)

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), and version 3 (2017), 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.

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

TCL 2022 version

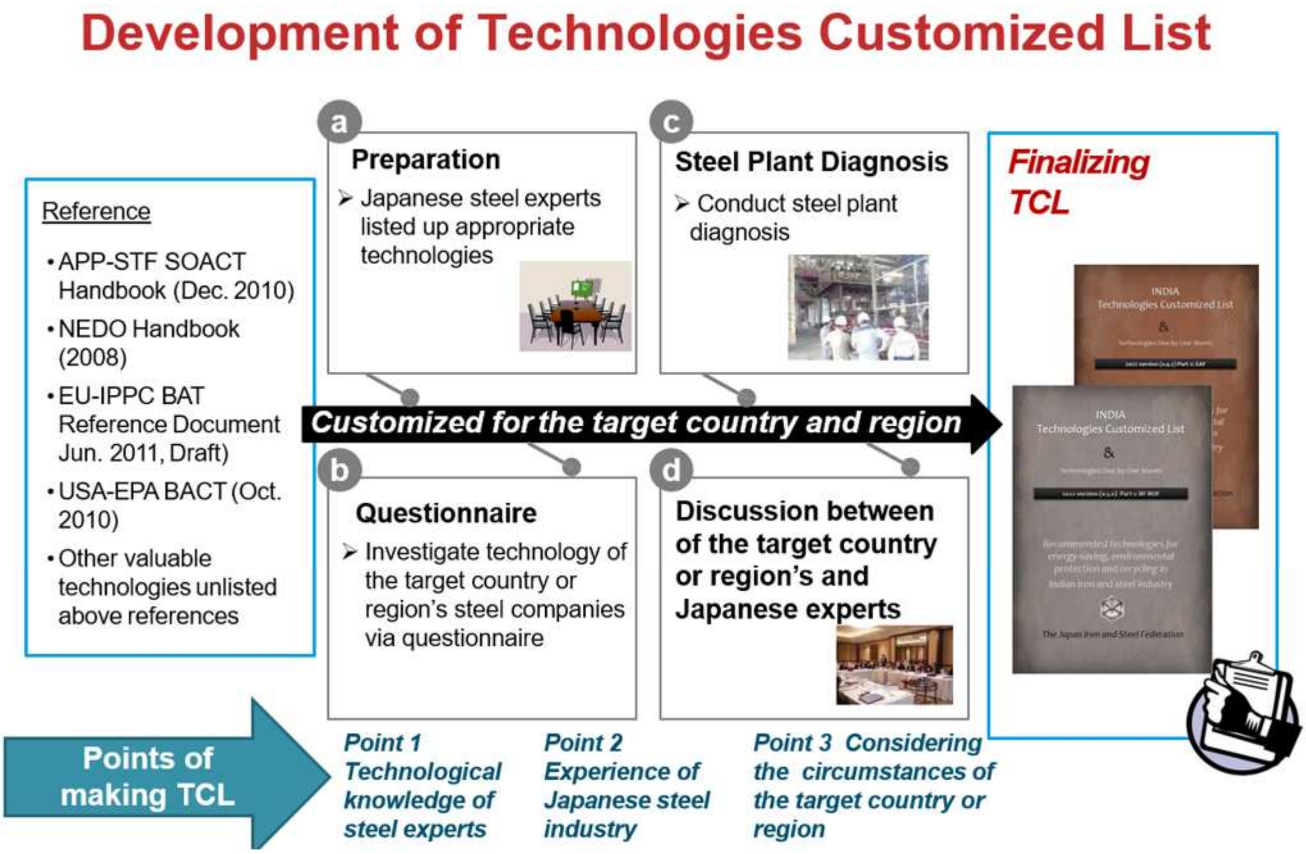
Development process of Technologies Customized List

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

Technologies Customized List & Technologies One by One Sheets
2022 version part-2: EAF (v.4.2)

Table of Contents

1. Technologies Customized List

Technologies Customized List for Energy Saving, Environmental Protection, and Recycling for Indian Steel Industry 2022 version part 2: EAF (v.4.2)

No.	ID	Title of technology	Technical description	Expected effects of introduction						Assumed investment cost	
				Electricity saving (kWh/t of product)	Thermal energy saving (GJ/t of product)	CO2 reduction (kg-CO2/t of product)	Profit of 2) Operation cost (US$/t of product, Japan)	Environmental benefits	Co-benefits	Assumed investment cost 4) (million US$ in Japan)	Payback time (year in Japan)
A. Energy Saving for Electric Arc Furnace (EAF)											
1	A-1	High temperature continuous scrap preheating EAF	Combination of the technologies of - Air tight structure - High temperature scrap preheating (over 700 degC) - Continuous preheated scrap charging - Automatic process control by using data logging - Post-combustion of generated CO gas - Dioxin decomposition by secondary combustion	150.0	-	135.75	21.45	- Decomposition and reduction of dioxin, dispersing dust, & noise	- Low electrode consumption (0.8 - 1.0 kg/ton-product at AC)	38.00	3.5
2	A-2	Medium temperature batch scrap preheating EAF	- High melting efficiency batch charging type EAF with SPH. - Preheated scrap temperature is about 250 - 300 degC. - Fully enclosed automatic charging system to keep working floor clean. - Minimize scrap oxidation by temperature controlling - Material limitation free	40.0	-	36.20	5.72	- Reduction of dioxin emission, dispersing dust, & noise	-No limit of material for high quality products as like stainless steel.	10.00	3.5
3	A-3	High efficiency oxy-fuel burner/lancing for EAF	- Supersonic or coherent burner - Accelerate scrap melting during melting stage - Facilitate slag foaming during refining stage over the bath	14.3	-	12.94	2.04	-	- Reduction of nitorgen in steel for quality improvement	2.05	2.0
4	A-4	Eccentric bottom tapping (EBT) on existing furnace	- Slag free tapping - Reliable stopping and scraping mechanism	15.0	-	13.58	2.15	-	- Increase in Fe & alloy yield, productivity - Improve steel quality	4.00	3.7
5	A-5	Ultra high-power transformer for EAF	- Long arc by high voltage and low ampere operation - Water cooled wall-panel to protect refractories	15.0	-	13.58	2.15	-	- Procuctivity increase	5.66	5.3
6	A-6	Optimizing slag foaming in EAF	- Proper chemical ingredients of slag - High efficient burner and/or lance - Controlled O2 & C injection into EAF proper position - Keeping slag thickness with air-tight operation	6.0	-	5.43	0.86	- Noise reduction & working floor cleaning	-	1.50	3.5
7	A-7	Optimized power control for EAF	- Data logging and visualization of melting process - Automatic judgement on meltdown and additional scrap charge - Automatioc phase power independent control for well-balanced melting	15.0	-	13.58	2.15	-	- Productivity increase - Manpower saving	2.50	2.3
8	A-8	Operation support system with EAF meltdown judgment	Automatic Rapid Melting system - Data logging - Optimum electric power control - Alloy calculation - Automatic meltdown Judgment	6.0	-	5.43	0.74	-	- Productivity increase - Manpower saving - Operation standardization	0.65	1.5
9	A-9	Low NOx regenerative burner system for ladle preheating	- Regenerating burner use - High Energy Saving (about 40 %) - Automatic control - FDI Combustion	-	0.20	12.62		- NOx reduction	Contribute to better atmosphere around at workfloor	0.40	0.2
10	A-10	Oxygen burner system for ladle preheating	- Rapid and high temperature ladle heating by oxygen burner - Automatic control - High Energy Saving (about 40 %)	-	0.20	12.62		- NOx reduction	Contribute to better atmosphere around at workfloor	0.30	0.2
11	A-11	Waste heat recovery from EAF	- Waste heat boiler based on the OG boiler technology - Specified for splash and dust containing	132.0	-	119.46	18.88	-	-	60.00	6.4
12	A-12	Energy saving for dedusting system in EAF meltshop	- Damper openings and exhaust fan rotation are controlled in consonance - Combination of VVVF and proper damper opening	6.0	-	5.43	0.86	- Better working floor & atmosphere	-	0.80	1.9
13	A-13	Bottom stirring/stirring gas injection	- Inject innert gas (Ar or N2) into the bottom of EAF - Better heat transfer steel quality	18.0	-	16.29	2.57	-	- Fe yield increase 0.5 %	0.26	0.2
14	A-14	Induction type tundish heater	- Application of induction heating - Possible to uniformize temperature in 3 minutes after power supply	3.0	-	2.72	0.43	-	-	1.00	4.7
15	A-15	Scrap pretreatment with scrap shear	- Long size or low bulk-density scrap is shredded and packed. - Scrap pretreatment decreases the scrap-charging frequency, which will lead to energy saving.	20.0	-	18.10	2.86	-	Fe yield increase in 1.5 % (by Non-integrated steel producer's association)	3.80	2.7
16	A-16	Arc furnace with shell rotation drive	- By rotating furnace shell 50 degree back-and-force, cold spot will be decreased to realize smooth melting. - Assumed investment cost is the increase from the newly constructed conventional EAF.	32.0	-	28.96	4.58	-	- Decreasing power-on time, melting fuel, and refractory material	6.00	2.6

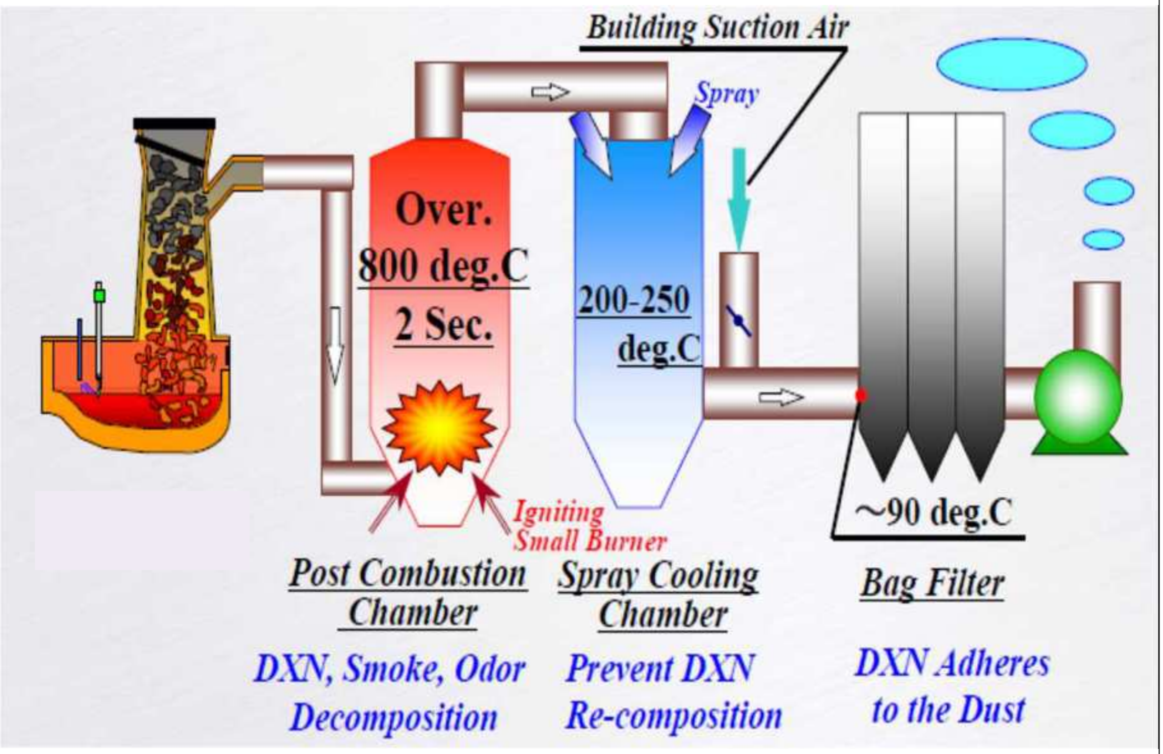
				Expected effects of introduction					Assumed investment cost	
No.	**ID**	**Title of technology**	**Technical description**	**Electricity saving**	**Thermal energy saving**	**Profit of 2) Operation cost**	**Environmental benefits**	**Co-benefits**	**Assumed investment cost 4)**	**Payback time**
				(kWh/t of product)	**(GJ/t of product)**	**(US$/t of product, Japan)**			**(million US$ in Japan)**	**(year in Japan)**
B. Environmental Protection for Electric Arc Furnace										
17	B-1	Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF	- Improved design configuration of the direct evacuation for treating hot unburned gas from much fuel use - Minimize dust and gas dispersion from EAF with enough capacity and suitable control	-	-	-	- Better workfloor & environment	-	-	
18	B-2	Floating dust control in EAF meltshop	- Analyze air flow in EAF building	-	-	-	- Restrict dust loading on working floor to less than 5 mg/m^3	-	**1.00**	
19	B-3	Dioxin adsorption by activated carbon for EAF exhaust gas	- Packaged cartridges of activated carbon fixed at the exit of bag-filter adsorbs and removes dioxins and heavy metals to an extremely low levels	-	-	-	- Dioxin will be lower than 0.5 ng TEQ/m^{3}N	-	-	
20	B-4	Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas	- Cooling direct evacuation gas by mixing with building dedusting gas	-	-	-	- Dioxin will be lower than 5.0 ng TEQ/m^{3}N	-	-	
21	B-5	Dioxin absorption by 2 step bagfilter technology for EAF exhaust gas	- 2 step bag system can remove over 99% DXN's from EAF. - This system provide a clean working environment. - Effective evacuation decrease the consumption of electricity.	-	-	-	- Dioxin will be lower than 0.5 ng TEQ/m^{3}N	-	-	
22	B-6	PKS charcoal use for EAF	- Charcoal made from PKS can be used instead of injected coke into EAF.	-	-	-	- 39,000 ton-CO2/y GHG reduction	-	-	
C. Material Recycle for Electric Arc Furnace										
23	C-1	EAF dust and slag recycling system by oxygen-fuel burner	- Zn recovery rate will be expected to be 95% -Remove heavy metals from dust and turn into harmless	-	-	-	-	- Zn material and heavy aggregate can be gained from EAF dust	-	
24	C-2	EAF slag agglomeration for aggregate use	- Molten slag is rapidly cooled by jet air, and becomes 0.5 - 3.0 mm heavy and strong ball. - Suited to use aggregate mixed with cement	-	-	-	- Slag satisfies the safety code	- Saved processing time: 10 minutes	**1.00**	
D. Energy Saving for Reheating Furnace										
25	D-1	Process control for reheating furnace	- Setting furnace temperature by targeted billet temperature curve - Precise air ratio control and O2 analysis in exhaust gas	-	**0.050**	**0.96**	-	-	**2.50**	**5.2**
26	D-2	Low NOx regenerative burner total system for reheating furnace	- High efficient and durable burner system	-	**0.189**	**3.61**	- CO2 & NOx Reduction	-	**8.00**	**4.4**
27	D-3	High temperature recuperator for reheating furnace	- Heat transfer area is expanded - Special material tube is used instead of stainless	-	**0.100**	**1.91**	-	-	**1.50**	**1.6**
28	D-4	Fiber block for insulation of reheating furnace	- Low thermal conductivity - High temperature change response (low thermal-inertia)	-	**0.039**	**0.75**	- Reduction of Heat accumulation	-	**1.50**	**4.0**
29	D-6	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)	**-40.0**	**1.45**	**21.99**	- Better working floor & atmosphere	-	**1.00**	**0.1**
30	D-7	Oxygen enrichment for combusiotn air	Thermal energy will be reduced with the decrease in the volume of exhaust gas. Assumed oxygen percentage in combustion air is 39 % in the study. Equipment of oxygen generator is not estimated, it is sometime rental use. Only electric power to generate pxygen is examined (0.5 kWh/m3N)	**-23.6**	**0.26**	**1.59**	- Smaller exhaust gas volume from the stack		-	
E. Common systems and General Energy Savings										
31	E-1	Inverter (VFD; Variable Frequency Drive) drive for motors	Applying the Multi-Level Drive for motors enables to save energy cost from vane and valve control (constant speed motor). ･Eco-Friendly ･Power Source Friendly ･Less Maintenance ･Motor Friendly	**13%**	-	-	- CO2 Reduction	-	**1.50**	
32	E-2	Energy monitoring and management systems	- Energy data are collected in process computer for evaluation	-	**0.120**	**2.29**	-	-	-	
33	E-3	Management of compressed air delivery pressure optimization	- Energy saving in compressors requires consideration of the following points. * Selection of the appropriate capacity * Reduction in delivery pressure	**285 MWh/y**	-	-	-	-		
34	E-4	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**	**1.71**	- CO2 Reduction	-	**2.90**	**2.9**

2. Technologies
One by One Sheets

A-1

A. Energy Saving for Electric Arc Furnace (EAF)

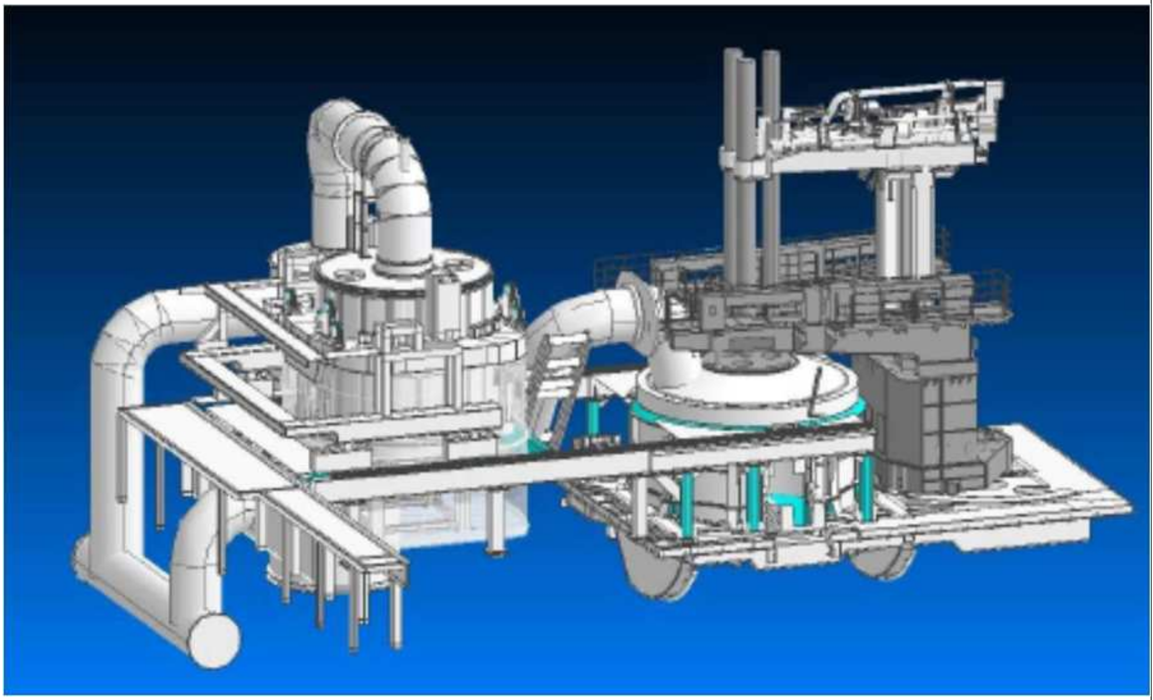
High temperature continuous scrap preheating EAF

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		Preheating scraps with high-temperature exhaust gas is possible because the preheating shaft and melting chamber are directly and rigidly connected, so the scraps are continually present, from the steel to preheating areas. This enables high-temperature preheating of the scraps, resulting in a significant reduction of power consumption. The melting chamber is sealed off from outside air, to prevent the excess air inlet. It prevents over oxidation of scrap under high temperature preheating.As this equipment keeps always flat bath operation, electrode consumption is significantly improved. Furthermore, the electric facilities necessary to meet power quality regulation can be drastically reduced on it may not even unnecessary depending on required regulation. Dioxins are decomposed through an exhaust gas combustion chamber and rapid quench chamber in the exhaust gas duct system. Not only dioxins but also a volatile material that causes foul odors and white smoke will be decomposed and the dispersal of them are also prevented.The furnace prevents diluting of exhaust gasses. Therefore, the CO within the exhaust gas can be used as fuel, reducing the amount of fuel gas consumed.Flat bath operation dramatically reduces noise during operation. The reduction of power consumption also contributes to the reduction of emission of greenhouse gasses during power generation.
3. Expected Effect of Technology Introduction	･Electricity Saving	150 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	Decomposition of dioxin, reducing dispersing dust, & noise
	･Co-benefits	Low electrode consumption (0.8 - 1.0 kg/ton-product at AC)
4. Japanese Main Supplier		JP Steel Plantech
5. Technologies Reference		SOACT 2nd Edition ("Ecological and Economical Arc Furnace"), Diagram from JP Steel Plantech
6. Comments		

A-2

A. Energy Saving for Electric Arc Furnace (EAF)

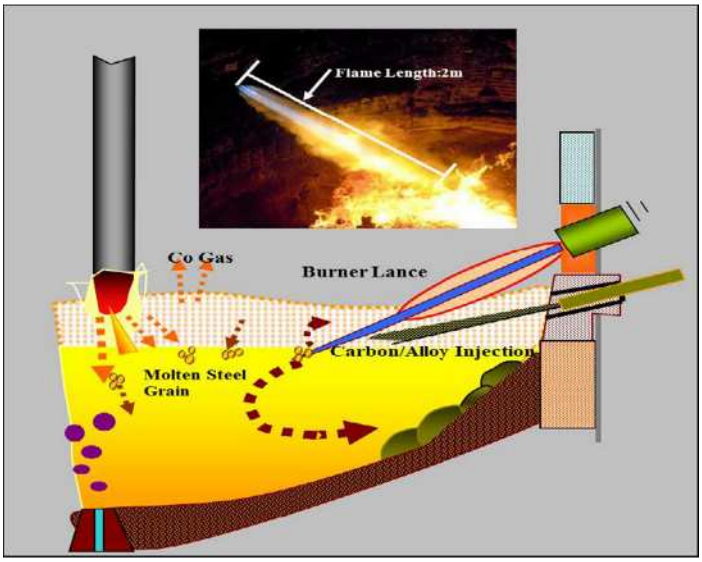
Medium temperature batch scrap preheating EAF

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- High melting efficiency batch charging type EAF with SPH. - Preheated scrap temperature is about 250 - 300 degC. - Fully enclosed automatic charging system to keep working floor clean. - Minimize scrap oxidation by temperature controlling - Material limitation free
3. Expected Effect of Technology Introduction	・Electricity Saving	40 kWh/ton-product
	・Thermal Energy Savings	-
	・Environmental benefits	Reduction of dioxin emission, dispersing dust & noise
	・Co-benefits	No limit of material for high quality products as like stainless steel.
4. Japanese Main Supplier		Daido Steel
5. Technologies Reference		
6. Comments		

A-3

A. Energy Saving for Electric Arc Furnace (EAF)

High efficiency oxy-fuel burner/lancing for EAF

Item		**Content**
1. Process Flow or Diagram		 New type of burner has been used to inject carbon and oxygen from side wall and closed slag door. The buener can realize evenly distributed slag-foaming and post-combustion without fully Coherent buner can make long and sharp oxygen jet, which works instead of oxygen lance. Oxygen jet from the center hole is resricted to expand by the combustion around the jet, the combustion is generated by the fuel and oxygen from the peripheral 
2. Technology Definition/Specification		'Conventional oxygen lances inserted through slag door causes; - Local oxygen input near the slag door - Uneven slag foaming through the bath - Uneven post-combustion of generated CO - Much hot gas escape caused by the cold air infiltration through the slag door
3. Expected Effect of Technology Introduction	･Electricity Saving	14.3 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Reduction of nitorgen in steel, quality improvement
4. Japanese Main Supplier		Daido Steel, Nikko, JP Steel Plantech
5. Technologies Reference		SOACT 2nd edition (Add the word "High efficiency" to SOACT item for up-to-date oxygen use), Diagram from Nikko
6. Comments		<Source of "Electricity saving"> 0.14 GJ/ton in SOACT ---> 0.14 x 9.8/1000 = 14.3 kWh/ton

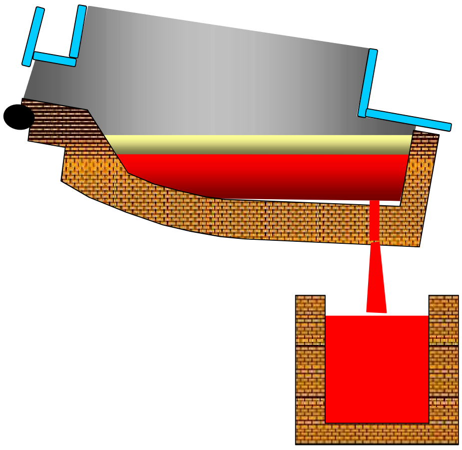
A-4

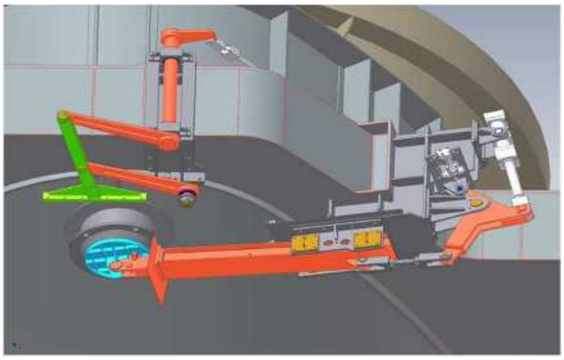
A. Energy Saving for Electric Arc Furnace (EAF)

Eccentric bottom tapping (EBT) on existing furnace

Item	Content

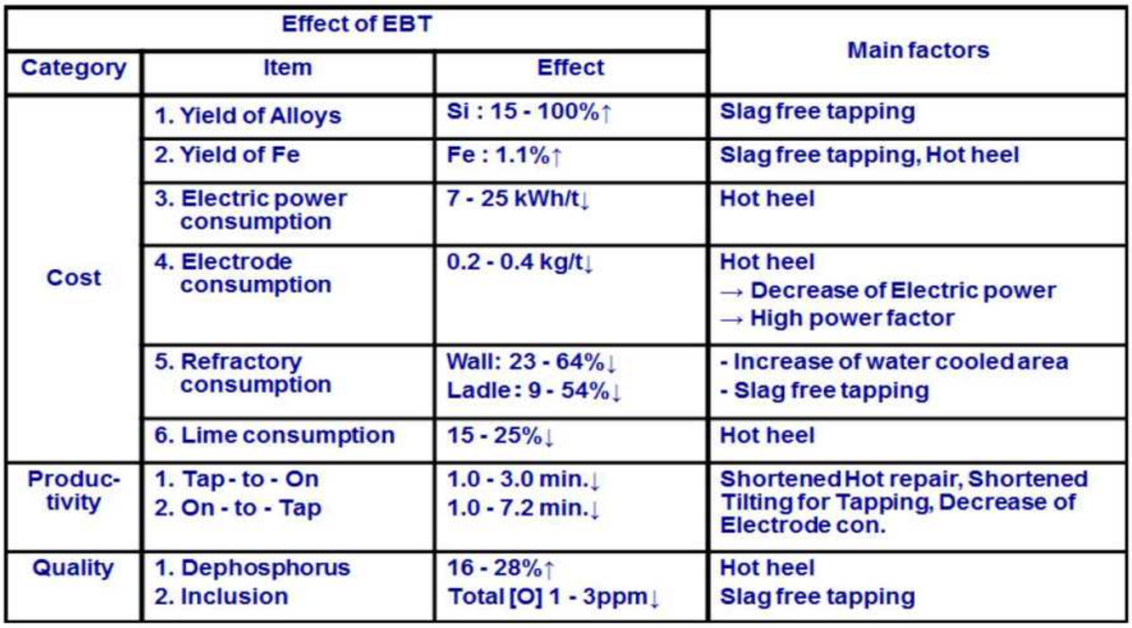
1. Process Flow or Diagram





EBT concept and tapping

Effect of EBT



Effect of EBT			Main factors
Category	Item	Effect	
Cost	1. Yield of Alloys	Si : 15 - 100%↑	Slag free tapping
	2. Yield of Fe	Fe : 1.1%↑	Slag free tapping, Hot heel
	3. Electric power consumption	7 - 25 kWh/t↓	Hot heel
	4. Electrode consumption	0.2 - 0.4 kg/t↓	Hot heel → Decrease of Electric power → High power factor
	5. Refractory consumption	Wall: 23 - 64%↓ Ladle: 9 - 54%↓	- Increase of water cooled area - Slag free tapping
	6. Lime consumption	15 - 25%↓	Hot heel
Produc-tivity	1. Tap - to - On 2. On - to - Tap	1.0 - 3.0 min.↓ 1.0 - 7.2 min.↓	Shortened Hot repair, Shortened Tilting for Tapping, Decrease of Electrode con.
Quality	1. Dephosphorus 2. Inclusion	16 - 28%↑ Total [O] 1 - 3ppm↓	Hot heel Slag free tapping

2. Technology Definition/Specification

- Molten steel is tapped through the hole at the furnace bottom.
' - Tilting angle for tapping is smaller then conventional sput tapping, and quick tappping and returning are possible.
' - Tapping hole is plugged with silicon sand after tapping, which is held by stopping mechanism.

' - Slag free tapping is possible
- Reliable stopping and scraping mechanism to avoid leakage

3. Expected Effect of Technology Introduction		
	･Electricity Saving	15 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Increase in Fe & alloy yield, and productivity Improve steel quality

4. Japanese Main Supplier	JP Steel Plantech, Daido Steel, Nikko
5. Technologies Reference	EPA-BACT (Sep. 2014), Diagram from JP Steel Plantech

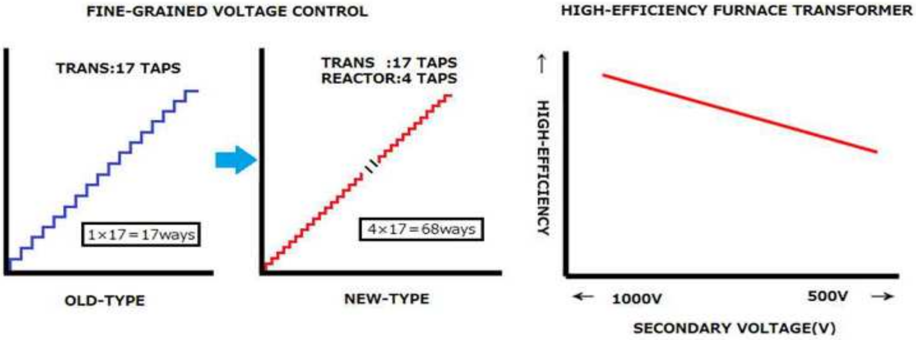
6. Comments

<Preconditions on calculating effects and investment costs>
- Values of "Electricity saving" are based on the
  EPA-BACT (Sep. 2014) & equipment supplier's rough estimation
- "Profit" does not include such other advantages than electricity saving

A-5

A. Energy Saving for Electric Arc Furnace (EAF)

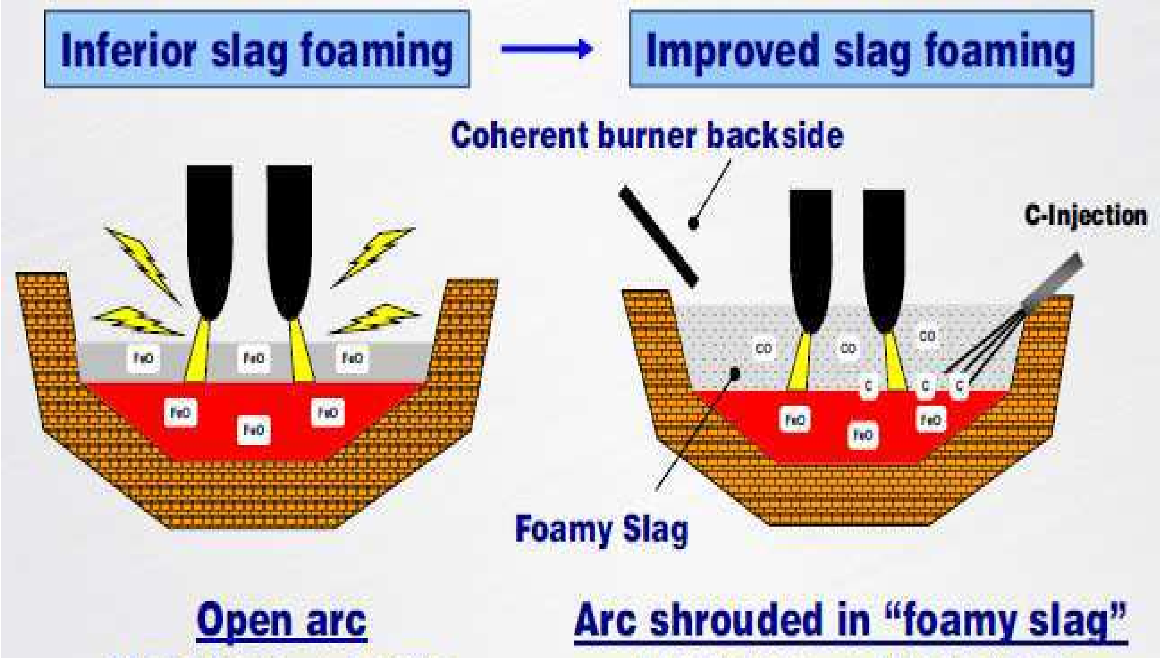
Ultra high-power transformer for EAF

Item		Content
1. Process Flow or Diagram		  
2. Technology Definition/Specification		In the conventional system, series reactor was used for the early melting stage in order to stabilize arc and control of a flicker . Since High-Efficiency Furnace Transformer provides high impedance at early melting stage, series reactor is not required, though the same performance is achieved. - Reduce electric power consumption - Reduce electrode consumption - Shorten tap to tap time 'In addition, it will conduct a fine-grained control by adding a reactor.
3. Expected Effect of Technology Introduction	･Electricity Saving	15 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Increase productivity
4. Japanese Main Supplier		Fuji Electric, JP Steel Plantech, Daido, Nikko
5. Technologies Reference		EPA-BACT ("Transformer efficiency - ultra-high power transformers"), Diagram from Nikko
6. Comments		<Preconditions on calculating effects> - "Electricity saving" 15 kWh/ton-product comes from EPA-BACT, assuming that 44 MVA transformer for 80 ton EAF is revamped to 55 MVA.

A-6

A. Energy Saving for Electric Arc Furnace (EAF)

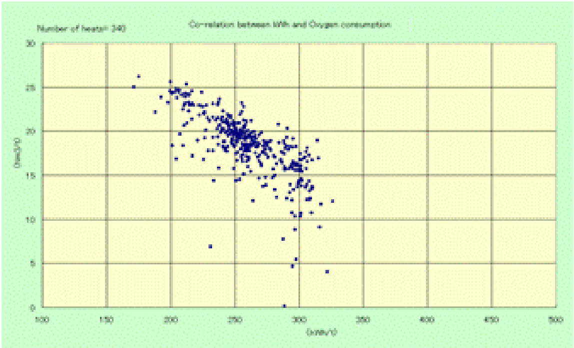
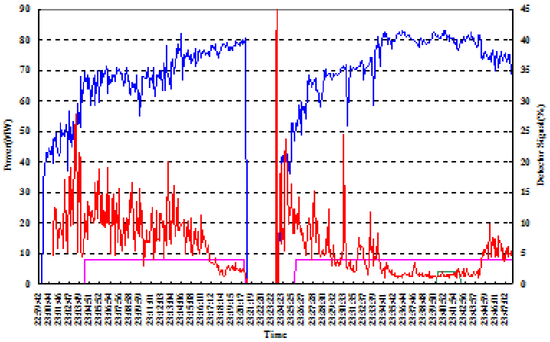
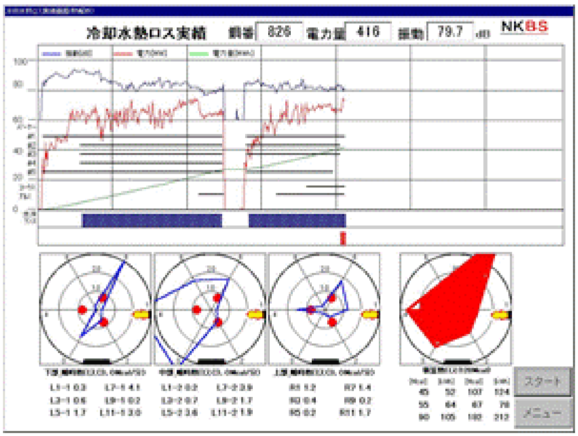
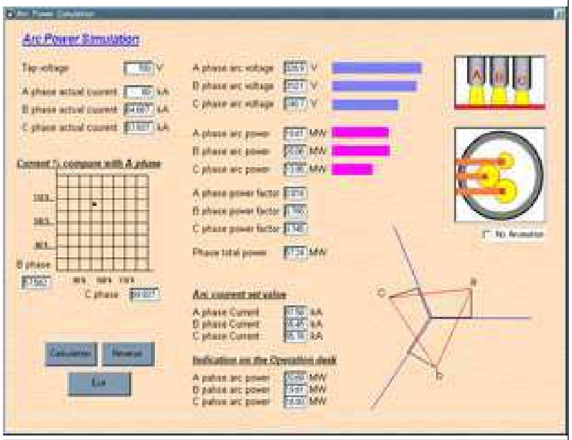
Optimizing slag foaming in EAF

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- Proper chemical ingredients of slag (Basicity 1.5 - 2.2, FeO 15 - 20 %) - High efficient burner and/or lance - Controlled O2 & C injection into EAF proper position - Keeping slag thickness with air-tight operation
3. Expected Effect of Technology Introduction	･Electricity Saving	6 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	Noise reduction & working floor cleaning
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel, Nikko
5. Technologies Reference		SOACT 2nd Edition (Delete the word "Exchangeable Furnace and Injection Technology"), Diagram from JP Steel Plantech
6. Comments		<Source of "Electricity saving"> (1) 2.5 - 3 % energy saving in SOACT ---> 430 kWh/ton x 0.03 = 12.9 kWh/ton (2) The phenomenum is explained by several factors, 6 kWh/ton is reasonable (Japanese experts).

A-7

A. Energy Saving for Electric Arc Furnace (EAF)

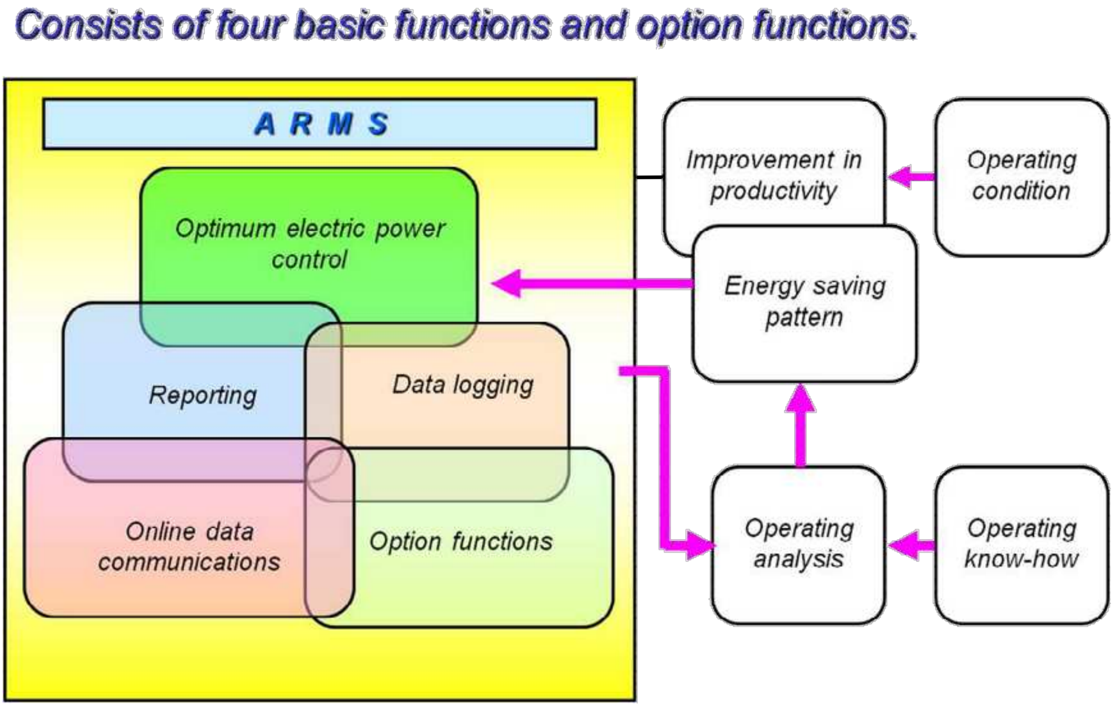
Optimized power control for EAF

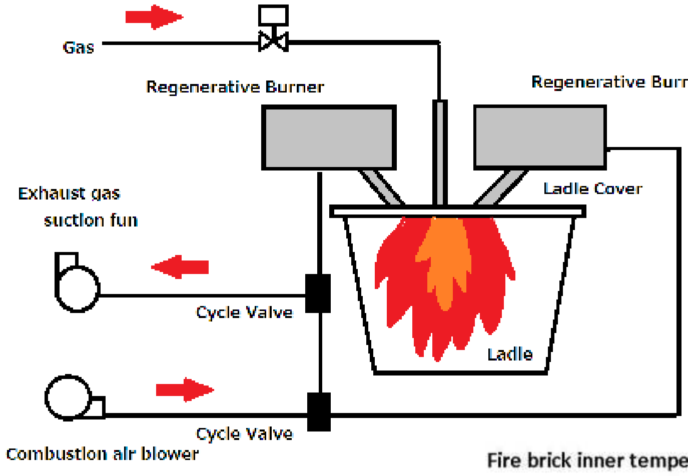
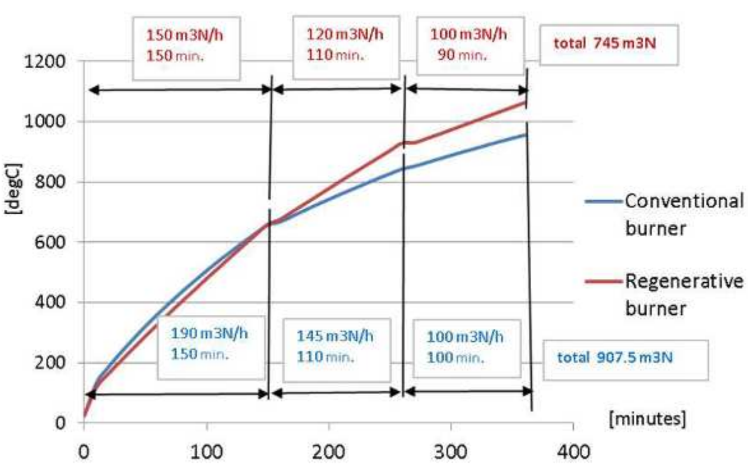
Item		Content
1. Process Flow or Diagram		 Statistical analysis  Slag foaming detection  Heat loss supervision  Power supply control for each
2. Technology Definition/Specification		- Data logging and visualization of melting process - Automatic meltdown and additional scrap charging judgement - Automatic phase power independent control for well-balance melting
3. Expected Effect of Technology Introduction	･Electricity Saving	15 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	Productivity increase Manpower saving
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech
5. Technologies Reference		SOACT 2nd Edition ("Improved Process Control (Neural Networks)"), Diagram from JP Steel Plantech
6. Comments		-

A-8

A. Energy Saving for Electric Arc Furnace (EAF)

Operation support system with EAF meltdown judgment

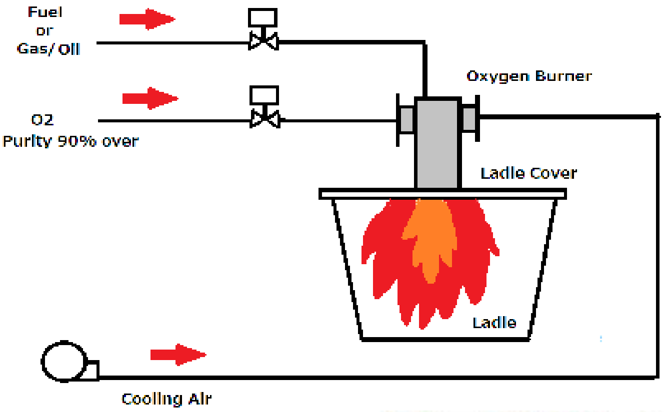
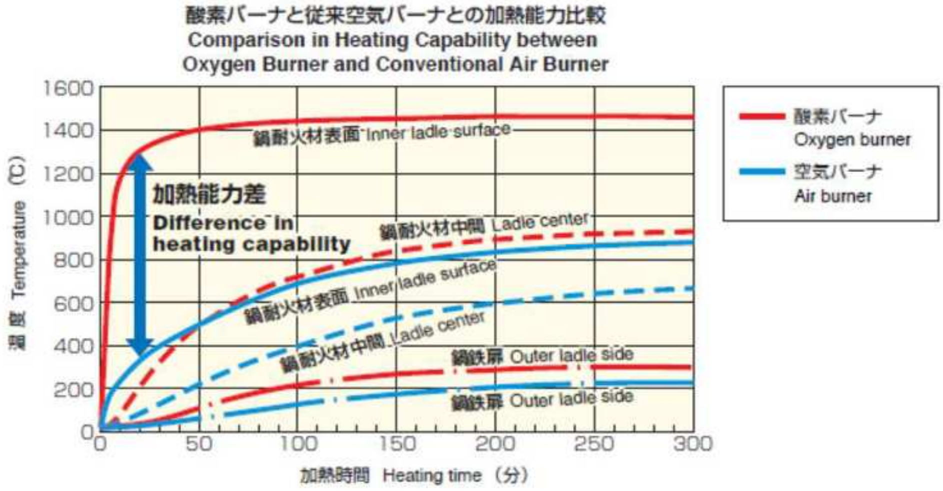
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		Automatic rapid melting system for EAF - Optimum electric power control - Reporting, Data logging and online data communications - Automatic meltdown Judgment - Power supply and electrode position control for each phase
3. Expected Effect of Technology Introduction	･Electricity Saving	6 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Productivity increase Manpower saving
4. Japanese Main Supplier		Daido Steel
5. Technologies Reference		Daido Steel
6. Comments		-

A-9		A. Energy Saving for Electric Arc Furnace (EAF) **Low NOx regenerative burner system for ladle preheating**
Item		**Content**
1. Process Flow or Diagram		 Fire brick inner temperature with natural gas 
2. Technology Definition/Specification		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.
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	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
	･Environmental benefits	Low NOx
	･Co-benefits	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
4. Japanese Main Supplier		Chugai-Ro, Nippon Furnace
5. Technologies Reference		
6. Comments		-

A-10

A. Energy Saving for Electric Arc Furnace (EAF)

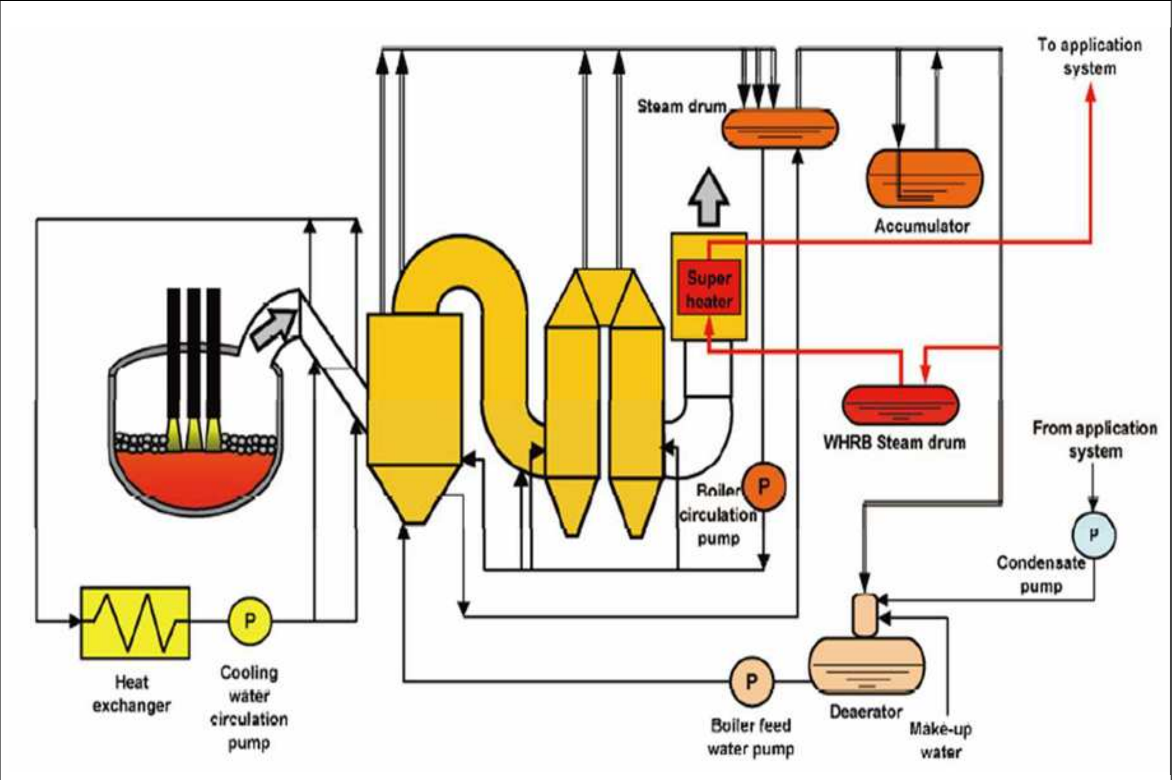
Oxygen burner system for ladle preheating

Item		Content
1. Process Flow or Diagram		 
2. Technology Definition/Specification		Oxygen combustion achieve rapid heating by high flame temperature. High flame temperature achieve high wall temperature, therefore it can be possible low temperature feeding of melted metal in to the ladle.
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	40 % fuel saving is expected comparing to existing preheater
	･Environmental benefits	Low NOx
	･Co-benefits	Higher brick temperature can allow lower tapping temperature for energy saving at EAF.
4. Japanese Main Supplier		Chugai-Ro, Nippon Furnace
5. Technologies Reference		Diagram from Chugai Ro, May contact to suppliers
6. Comments		-

A-11

A. Energy Saving for Electric Arc Furnace (EAF)

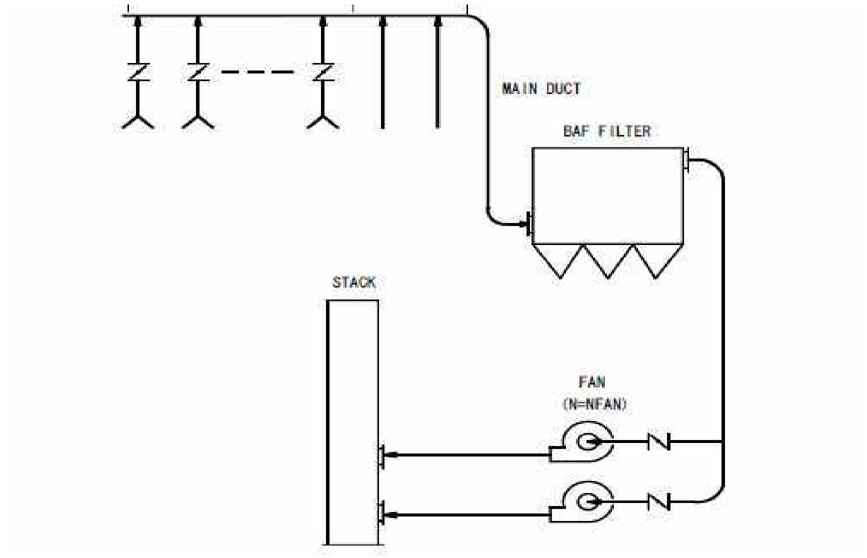
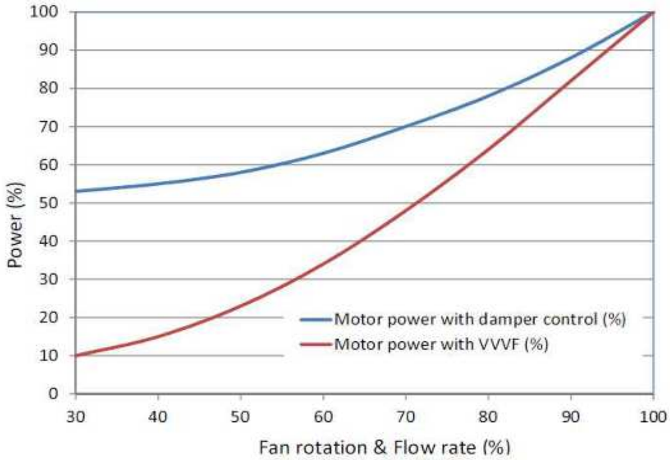
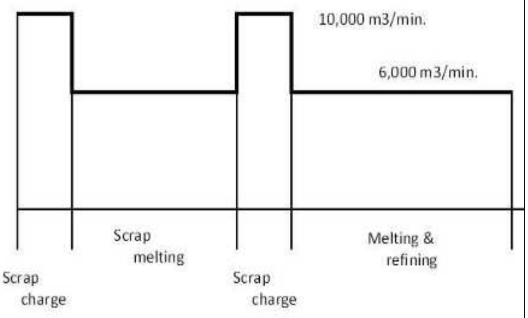
Waste heat recovery from EAF

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- Waste heat boiler based on the OG boiler technology - Specified for splash and dust containing - Main boiler is radiative type, and convective type super heater is located at the downstream of boiler to avoid clogging.
3. Expected Effect of Technology Introduction	･Electricity Saving	132 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech (yoshidah@steelplantech.co.jp, tel +81-45-471-3917 fax +81-45-471-4002)
5. Technologies Reference		Diagram from JP Steel Plantech, May contact to JP Steel Plantech
6. Comments		<Preconditions on calculating effects> - Power generation is 248,000 MWh/year with two 150 ton EAFs for DRI - Assumed annual production by two 150 ton EAF = 500,000 / 80 x 150 x 2 = 1,875,000 ton/y - Unit power generation = 248,000 x 1,000 / 1,875,000 = 132 kWh/ton-product - Suited to DRI continuous charging EAF, not scrap EAF

A-12

A. Energy Saving for Electric Arc Furnace (EAF)

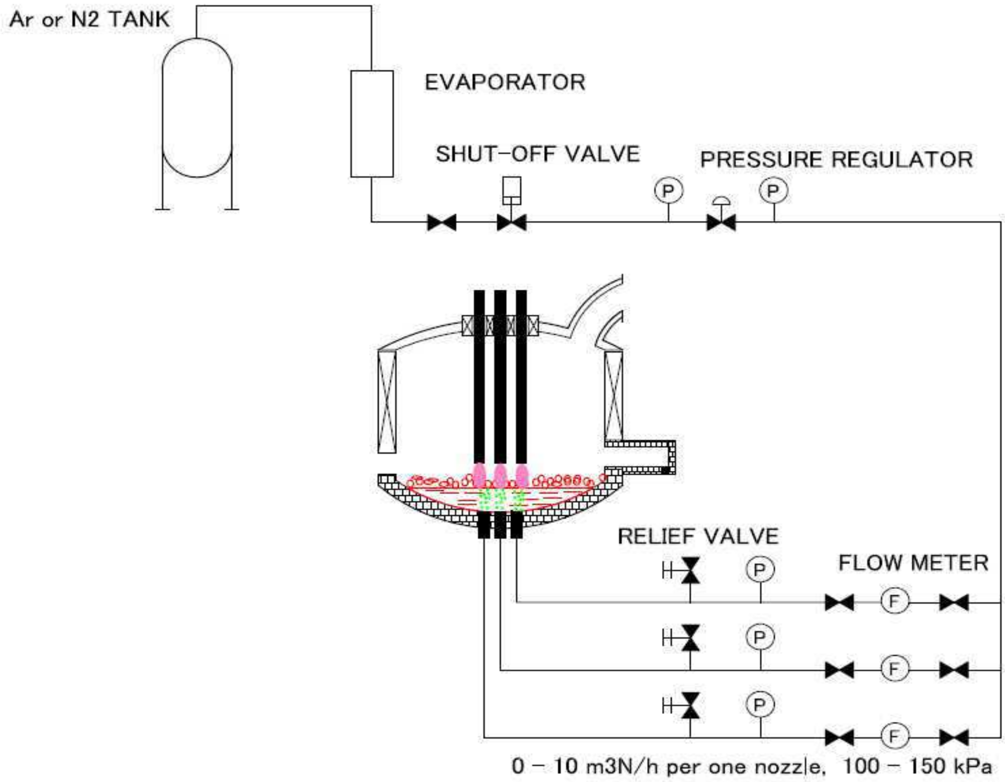
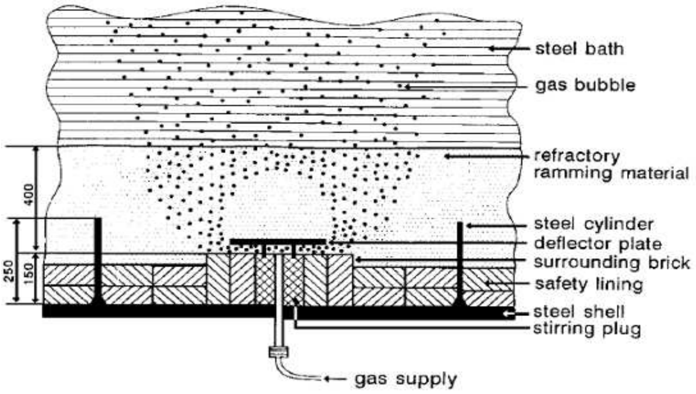
Energy saving for dedusting system in EAF meltshop

Item		Content
1. Process Flow or Diagram		   EAF operation and controlled flow rate for house-dedusting
2. Technology Definition/Specification		- Damper openings and exhaust fan rotation are controlled in consonance with the furnace operation pattern - Reducing fan rotation with VVVF sytem enables to save motor power, comparing to the simple damper control sytem.
3. Expected Effect of Technology Introduction	･Electricity Saving	6 kWh/ton-product (25 % of assumed unit power consumption)
	･Thermal Energy Savings	-
	･Environmental benefits	Better working floor and atmosphere
	･Co-benefits	-
4. Japanese Main Supplier		Fuji Electric, JP Steel Plantech, Daido, Nikko
5. Technologies Reference		Diagram from JP Steel Plantech
6. Comments		<Preconditions on calculating effects> Assumed electricity consumption for building dedusting is 24 kWh/ton-product, and 25 % power saving is expected.

A-13

A. Energy Saving for Electric Arc Furnace (EAF)

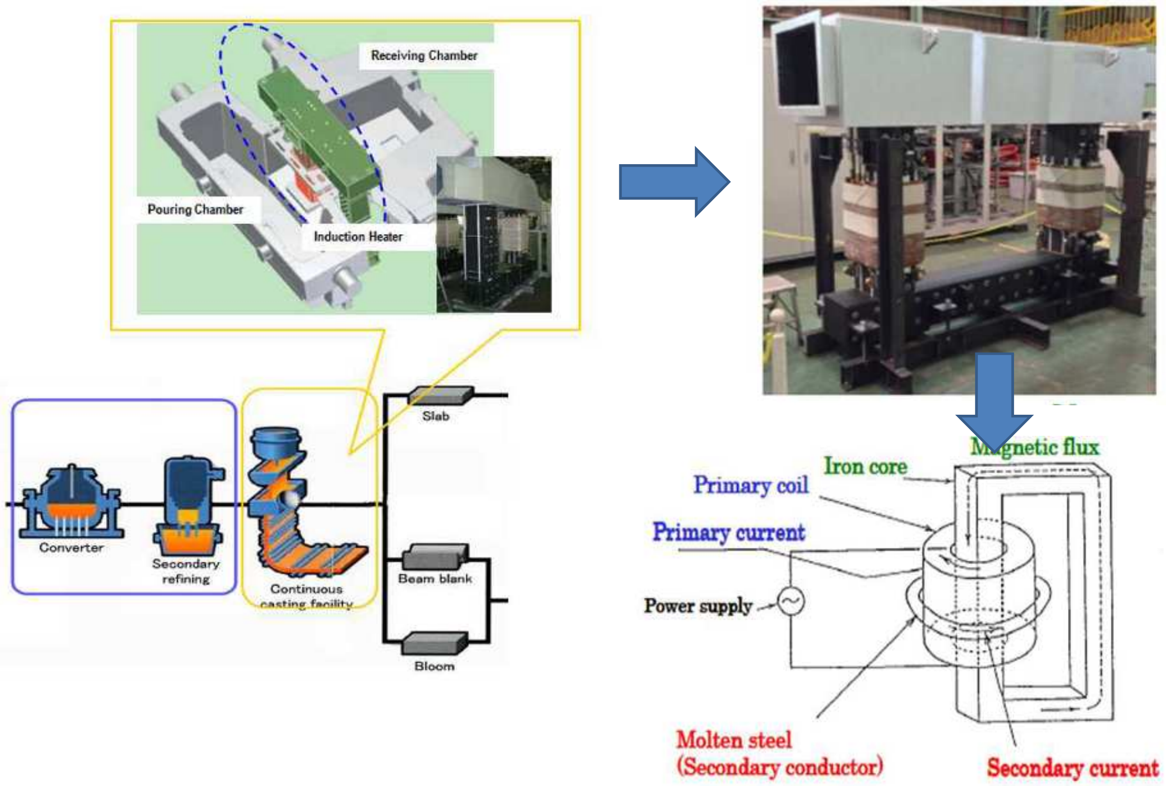
Bottom stirring/stirring gas injection

Item		Content
1. Process Flow or Diagram		  Schematic sketch of gas injection
2. Technology Definition/Specification		Inject inert gas (Ar or N2) into the bottom of EAF to agitate steel bath Expected effects : 2) - homogenize chemical composition and temperature in steel bath - accelerate chemical reaction between steel and slag - shorten tap-tap-time - save electrical energy - increase yields of iron and alloys
3. Expected Effect of Technology Introduction	･Electricity Saving	18 kWh/ton-product 1)
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Fe yield increase 0.5 % 1)
4. Japanese Main Supplier		Nikko, Daido Steel
5. Technologies Reference		1) EPA-BACT 2) Bottom-stirring in an electric-arc furnace:Performance results at ISCOR Vereeniging Works (The Journal of The South African Institute of Mining and Metallurgy, January 1994
6. Comments		

A-14

A. Energy Saving for Electric Arc Furnace (EAF)

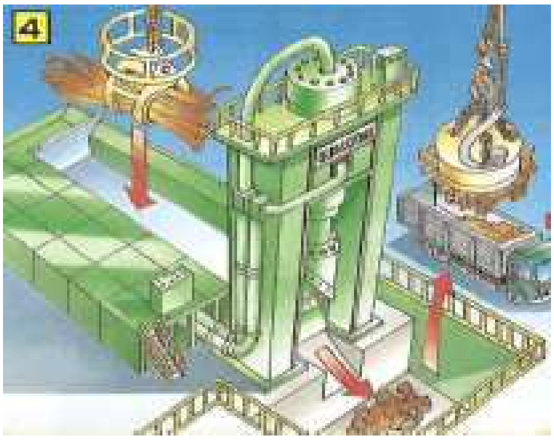
Induction type tundish heater

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		＜Features for Induction Tundish heater＞ 1.Uniformity of Element of Molten Steel:Agitation effect by electromagnetic force. 2.High Precision Temperature Control:Target Temp.±2.5degree. 3.High Heating Effciency：More than 90% by channel type inductor. 4.Ease of maintennance:Water cooled feeder with quick connector.Self-cooled type Induction coil and so on.
3. Expected Effect of Technology Introduction	･Electricity Saving	3 kWh / ton-product (Effect is calculated comparing to electricity consumption of plasma type heater)
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	1.Productivity increase 2.Quality improvement
4. Japanese Main Supplier		Fuji Electric
5. Technologies Reference		Fuji Electric
6. Comments		<Preconditions on calculating effects> - Assumed plasma type tundish heater is installed - Ladle capacity: 200 ton - Operated days: 30 days/month - Electricity intensity of heater: 13.7 kWh/ton - Heat efficiency: 70% - Pouring amount: 2.5 ton/min - Dissolution time: 80 min/charge - Rised temperature: 40 degeree C - Number of charges: 8 charges/day - Monthly production: 48,000 ton - Annual production: 576, 000 ton

A-15

A. Energy Saving for Electric Arc Furnace (EAF)

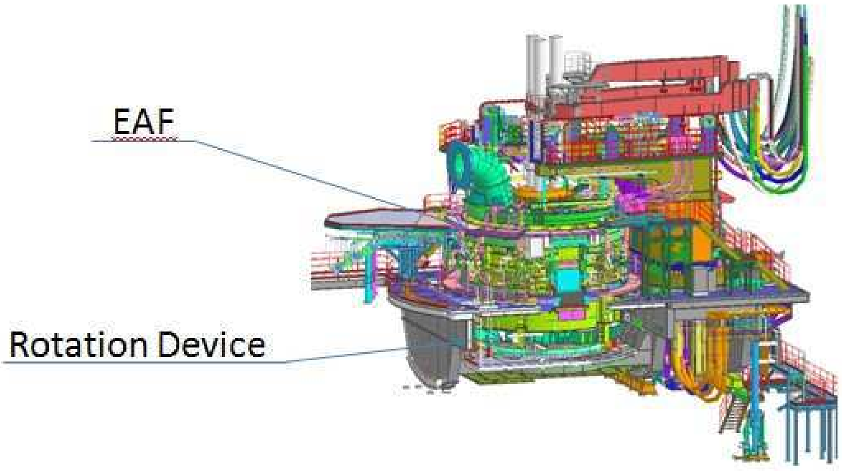
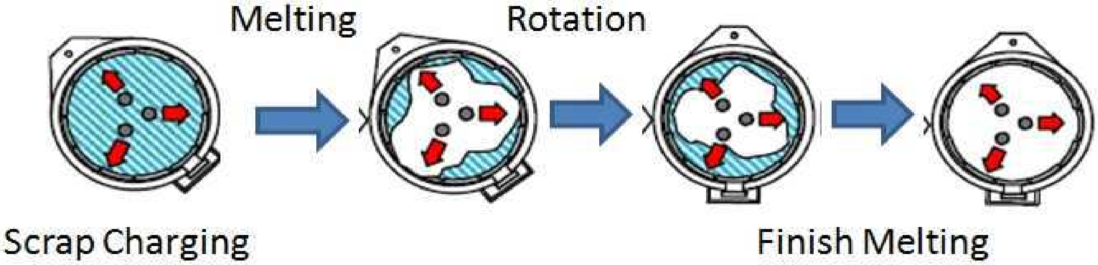
Scrap pretreatment with scrap shear

Item		Content
1. Process Flow or Diagram		   Before scrap pretreatment (0.3 ton/m3)  After scrap pretreatment (0.6
2. Technology Definition/Specification		- Long size or low bulk-density scrap is shredded and packed. - For example, bulk density of 0.3 m3/ton can be decreased to 0.6 with 1250 ton shear x 2 for 80 ton EAF. - Scrap pretreatment decreases the scrap-charging frequency, which will lead to energy saving.
3. Expected Effect of Technology Introduction	･Electricity Saving	20 kWh/ton-product (reported by Non-integrated steel producer's association of Japan)
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	- Fe yield increase in 1.5 %, TTT shortening
4. Japanese Main Supplier		Fuji Car Manufacturing
5. Technologies Reference		
6. Comments		

A-16

A. Energy Saving for Electric Arc Furnace (EAF)

Arc furnace with shell rotation drive

Item		Content
1. Process Flow or Diagram		 
2. Technology Definition/Specification		Furnace shell is rotated 50 dgree back-and-force Uniform scrap melting with furnace shell rotation - Shortening power-on time - Reduction in cooling water energy loss - Reduction in scrap cutting oxygen - Reduction in refractory repairing materials
3. Expected Effect of Technology Introduction	･Electricity Saving	32 kWh/ton-product
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	- No limit of material for high quality products - Reduction of refractory consumption
4. Japanese Main Supplier		Daido Steel
5. Technologies Reference		
6. Comments		

B-1

B. Environmental Protection for Electric Arc Furnace

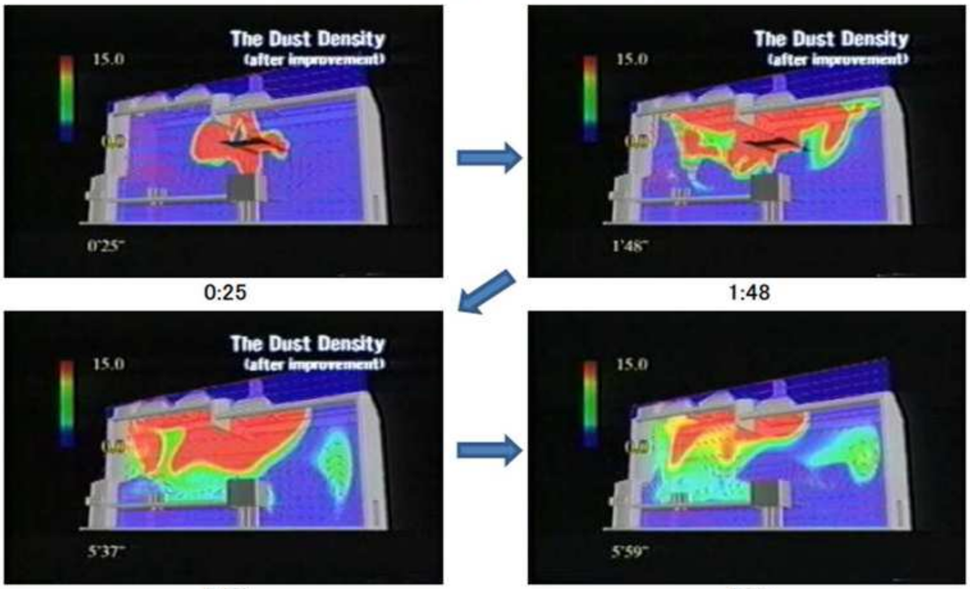
Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF

Item		**Content**
1. Process Flow or Diagram		
2. Technology Definition/Specification		- Improved design configuration of the direct evacuation for treating hot unburned gas from much fuel use - Minimize dust and gas dispersion from EAF with enough capacity and suitable control - Much fossil fuel use becomes possible to save electricity.
3. Expected Effect of Technology Introduction	・Electricity Saving	- When capacity increase is applied to the standard size EAF (30 m3N-O2/ton-steel, 20 m3N-natural gas/ton-steel, and 15 kg-carbon/ton-steel), expected electrical energy saving becomes as: 4 - 5 kWh/m3N-O2 8 - 9 kWh/m3N-natural gas 8 - 9 kWh/kg-carbon - Decrease in yield is assumed as 1 - 2 % per 10 m3N-O2/ton-steel.
	・Thermal Energy Savings	-
	・Environmental benefits	Better workfloor environment
	・Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel, Nikko
5. Technologies Reference		SOACT 2nd Edition Recent Progress of Steelmaking Technologiy in Electric Arc Furnace (1993, JISF)
6. Comments		

<table>
<tr><td rowspan="2">B-2</td><td colspan="2">B. Environmental Protection for Electric Arc Furnace</td></tr>
<tr><td colspan="2">Floating dust control in EAF meltshop</td></tr>
<tr><td>Item</td><td colspan="2">Content</td></tr>
<tr><td>1. Process Flow or Diagram</td><td colspan="2">

Transient analysis of flow and dust density in meltshop builiding

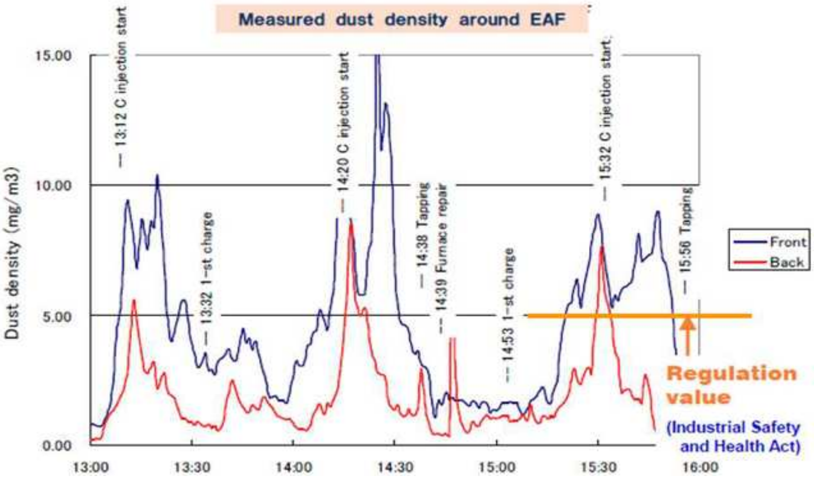
Simulated dust density after scrap charge to EAF



0:25 1:48

5:57 5:59

Floating dust density around EAF (by laser-scattering dust indicator)

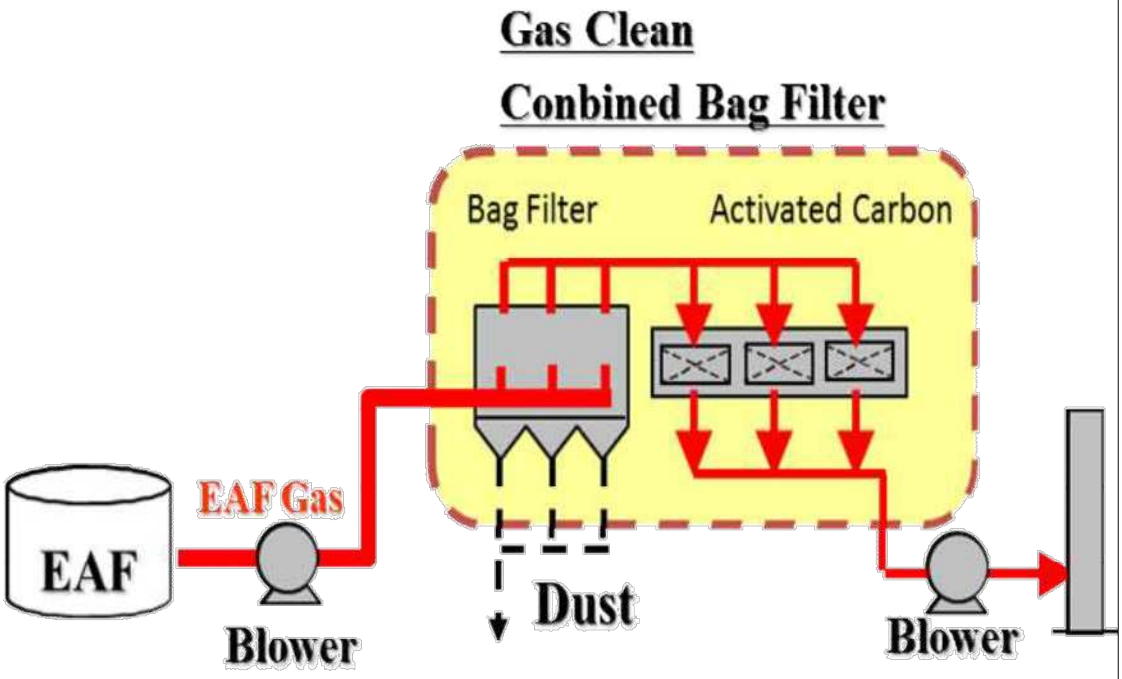


</td></tr>
<tr><td>2. Technology Definition/Specification</td><td colspan="2">- In modern EAF meltshop, fully enclosed building is required to avoid dust dispersion to the outside, but enclosed building raises workfloor pollution which affects workers health.
- Proper design and operation of dedusting system based on the flow analysis and real dust data are essential.
- Building and suction system revamping shall be executed based on the flow analysis.
- Target value of dust loading on working floor should be less than 5 mg/me, for example, specified in Industrial Safety and Health Act. in Japan</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>-</td></tr>
<tr><td>・Environmental benefits</td><td>Restrict dust loading on working floor to less than 5 mg/m3</td></tr>
<tr><td>・Co-benefits</td><td>-</td></tr>
<tr><td>4. Japanese Main Supplier</td><td colspan="2">JP Steel Plantech, Daido Steel</td></tr>
<tr><td>5. Technologies Reference</td><td colspan="2">Diagram from JP Steel Plantech, May contact to suppliers</td></tr>
<tr><td>6. Comments</td><td colspan="2"></td></tr>
</table>

B-3

B. Environmental Protection for Electric Arc Furnace

Dioxin adsorption by activated carbon for EAF exhaust gas

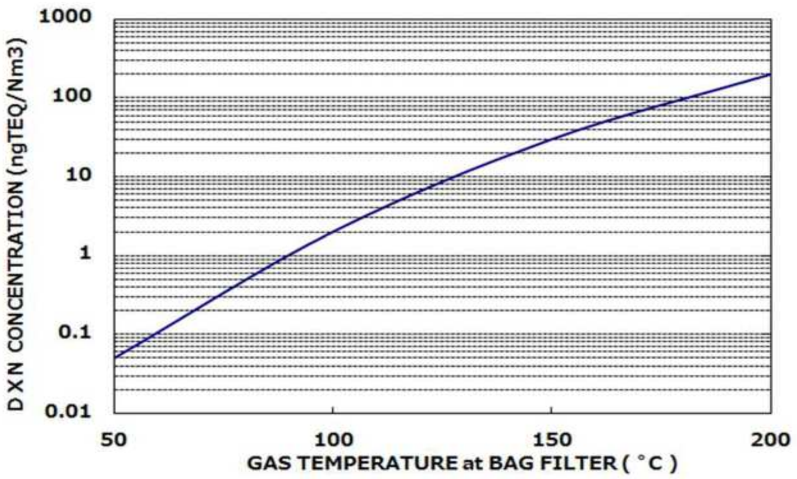
Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		A new dioxin-removal system passes exhaust gas through a layer of granular activated carbon with outstanding adsorption performance. High-performance activated carbon was developed exclusively for the system. Packaged cartridges with a unique structure allowing the system to adsorb and remove dioxins and heavy metals to an extremely low levels. A cartridge with a unique structure ensures improved contact efficiency between activated carbon and exhaust gas. Consequently, the filled quantity of activated carbon is considerably reduced allowing unparalleled compact size. In addition, amount of consumed activated carbon would be substantially reduced comparing to previous Activated Carbon Adsorption Tower. Furthermore, it would save electricity consumption of blower since its pressure loss would be lower than 0.5kPa (Approx. 50 mmAq) per a cartridge comparing to previous equipment.
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	-
	･Environmental benefits	Dioxin will be lower than 0.1 ng TEQ/m3N
	･Co-benefits	-
4. Japanese Main Supplier		JFE Engineering
5. Technologies Reference		Diagram from JFE Engineering
6. Comments		-

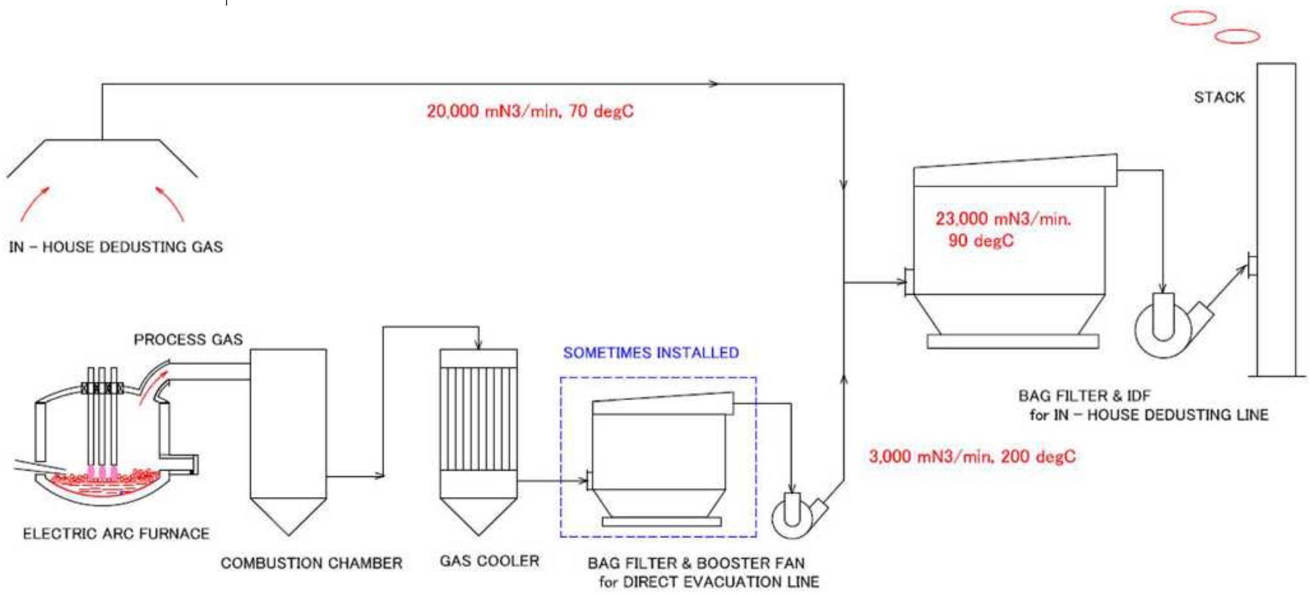
B-4

B. Environmental Protection for Electric Arc Furnace

Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas

Item	Content
1. Process Flow or Diagram	



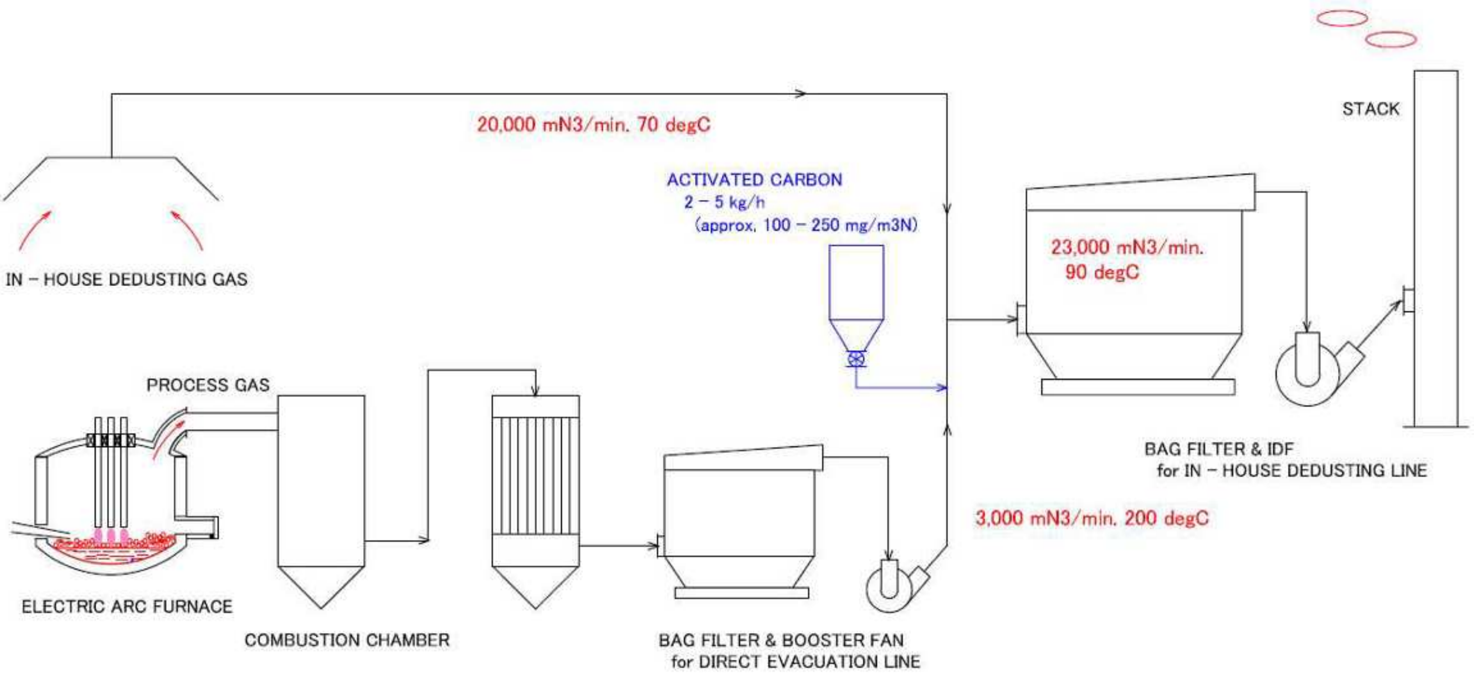


Item		Content
2. Technology Definition/Specification		- Dioxin concentration in the EAF exhaust gas at the exit of bag filter is strongly susceptible to the gas temperature. - In order to comply with the regulated value of 5.0 ngTEQ/m3N (applied to the existing EAF in JAPN), common technology is to mix the hot process gas with the in-house dedusting gas to cool down the gas through the bag filter. - Diokin seems to be captured by the oily dust which is accumulated on the surface of filter. - When gas temperature at the inlet of bag filter ascends up to about 110 degC, where oil is vaporised, dioxin concentration rapidly increases after bag filter even in a short time. - Collected duct at bag filter should be carefully treated, as it contains much dioxin. - This phenomenon is diffirent from the case of incinerators, where the dust does not contains oily substances.
3. Expected Effect of Technology Introduction	・Electricity Saving	-
	・Thermal Energy Savings	-
	・Environmental benefits	Dioxin will be lower than 5.0 ng TEQ/m3N
	・Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel, Nikko
5. Technologies Reference		
6. Comments		

B-5

B. Environmental Protection for Electric Arc Furnace

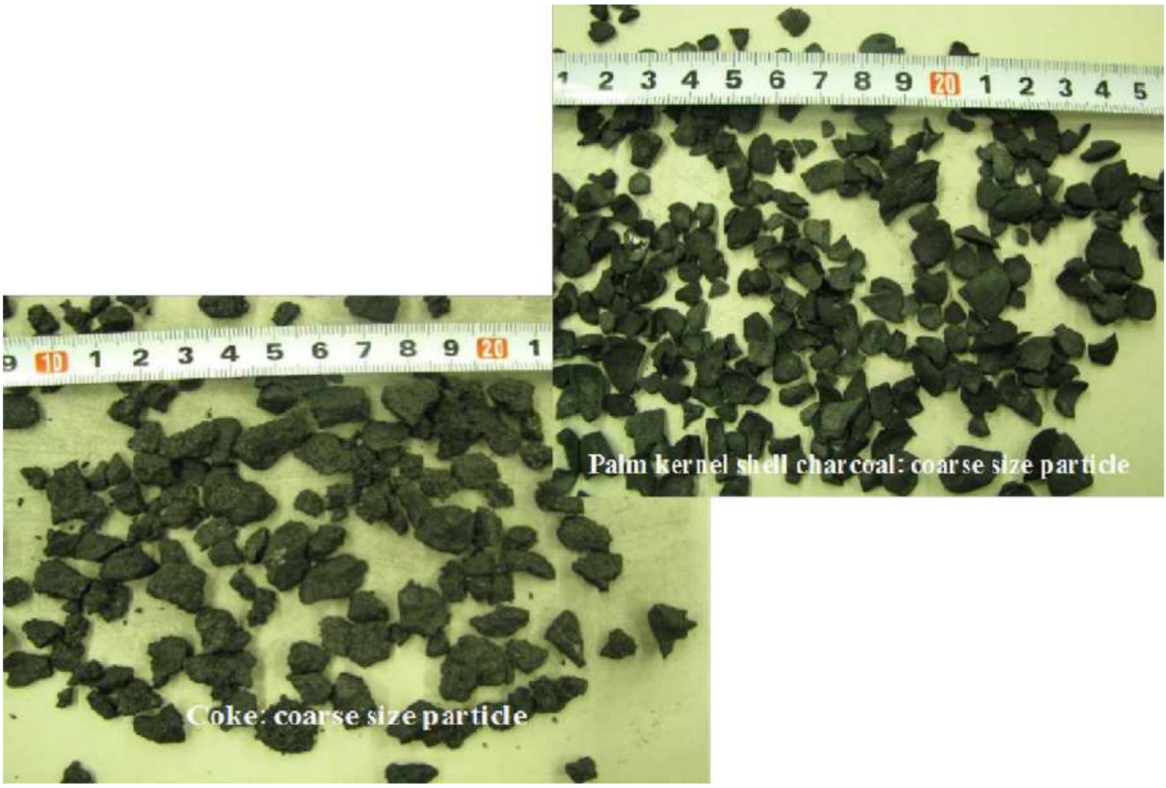
Dioxin adsorption by 2 step bagfilter technology for EAF exhaust gas

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- In order to comply with the more stringent regulation of 0.5 ngTEQ/m3N (applied to the new EAF in JAPN), two-step bag filter system is applied with the careful temperature control. - When 0.1 ngTEQ/m3N is requested from the authorities, for the cases of installation at dense-population are or industrial wastes treatment, activated carbon injection into the exhaust gas line is effective. - Dust loading in the process gas is much higher than that of in-house dedusting gas, therefore, activated carbon is injected into the gas which is dedusted with the primary bag filter. This activated carbon powder is accumulated on the filters of secondary bag filter and adsorbs dioxin.
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	-
	･Environmental benefits	Dioxin will be lower than 0.5 ng TEQ/m3N
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech, Daido Steel, Nikko
5. Technologies Reference		Diagram from JP Steel Plantech
6. Comments		-

B-6

B. Environmental Protection for Electric Arc Furnace

PKS charcoal use for EAF

Item		Content
1. Process Flow or Diagram		
2. Technology Definition/Specification		- Charcoal made from PKS (Palm Kernel Shell) has similar quality with coke commonly used for carbon injection into EAF - Higher heating value, lower sulfur content than fossil fuel coke - CO2 generated from charcoal is not counted as GHG (Green House Gas) - PKS charcoal is produced for the production of activated carbon in a small scale - Equipmet is very simple and can be constructed by local technology - Japanese supplier will provide with know-how
3. Expected Effect of Technology Introduction	･Electricity Saving	-
	･Thermal Energy Savings	-
	･Environmental benefits	39,000 ton-CO2/y GHG reduction from 500,000 ton/y EAF plant
	･Co-benefits	-
4. Japanese Main Supplier		JP Steel Plantech
5. Technologies Reference		
6. Comments		<Preconditions on calculating effects> Replaced coke at EAF : 25 kg/ton-steel C content in coke : 85 % CO2 generation from coke = 0.85 x 44 / 12 = 3.12 ton-CO2/ton-coke GHG reduction = 500,000 ton-steel/y x 0.025 x 3.12 = 39,000 ton-CO2/y

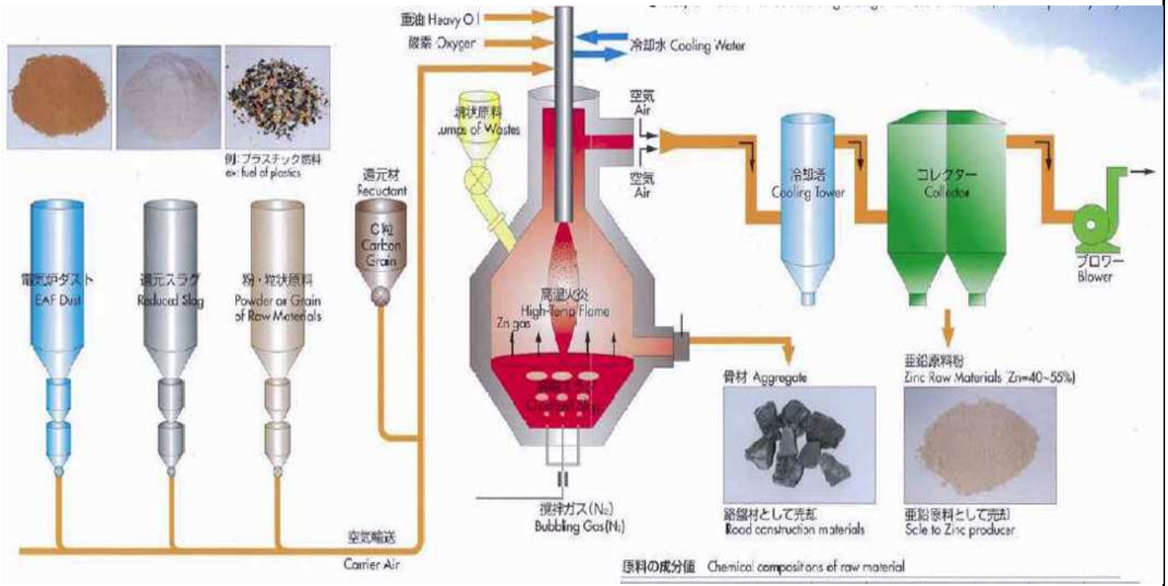
C-1

C. Material Recycle for Electric Arc Furnace

EAF dust and slag recycling system by oxygen-fuel burner

Item | **Content**

1. Process Flow or Diagram



2. Technology Definition/Specification

As dust and slag are melted down completely at high temperature, it is very effective against dioxin.
Produced valuable substances are completely harmless and can meet all environmental standards.
More than 99% of dioxin can be removed by high temperature treatment in the furnace and strong rapid cooling mechanism.
Besides electrical furnace dust and reduced slag, it is expected that this system will be applied to other waste treatments.
The equipment is simple and compact because of unnecessary pretreatment such as dust granulation and so forth.
Through simple design, excels in operability and suitable for on-site processing.
Also this system can recover expected 95% Zn from EAF dust as Zn law material.

3. Expected Effect of Technology Introduction

・Electricity Saving: -

・Thermal Energy Savings: -

・Environmental benefits: -

Example of the Leaching test result of Aggregate (Notice 46 by ME, Japan)

mg/l	Pb	Cd	Cr^{+6}	As	Hg	Se
Aggregate	<0.006	<0.001	<0.005	<0.005	<0.0005	<0.004
Regulation	0.01	0.01	0.05	0.01	0.0005	0.01

・Co-benefits:
Zn material can be gained from EAF dust
Heavy aggregate can be gained from EAF dust

4. Japanese Main Supplier: Daido Steel

5. Technologies Reference: Diagram from Daido Steel, May contact to Daido Steel

6. Comments: -

Example of the chemical composition of raw material

(wt%)	T-Fe	CaO	SiO_2	Zn	Pb	Cl	F
Zn raw material	6.5	2.5	0.9	52.3	8.5	7.7	1.4
Aggregate	40.1	17.8	10.2	2.1	<0.01	0.4	0.3

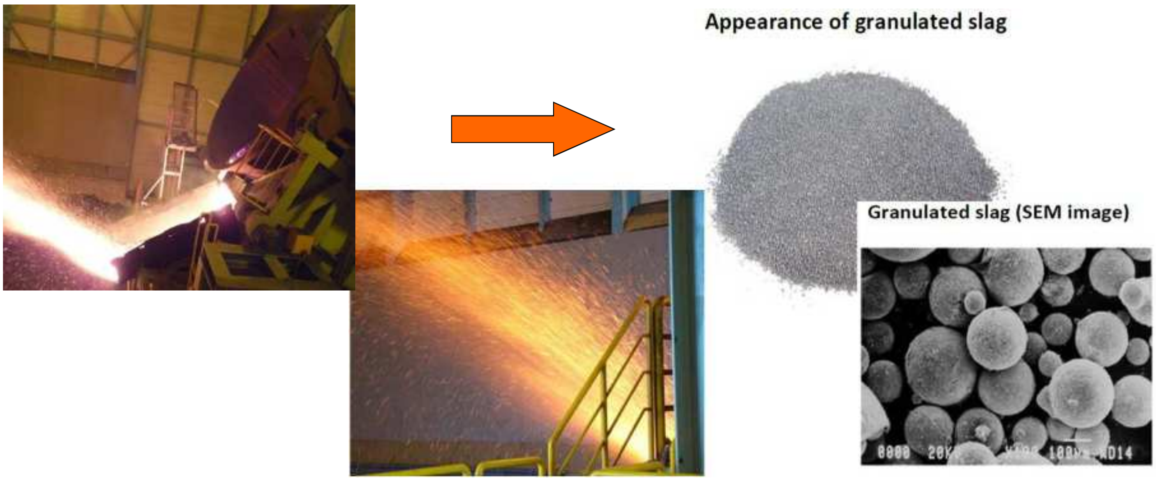
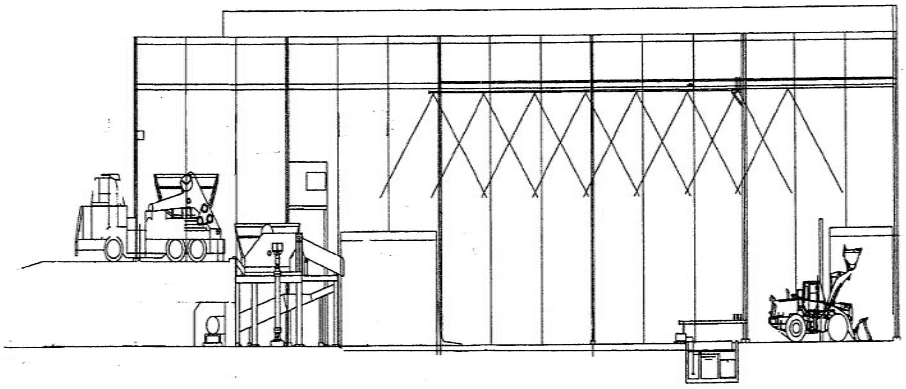
Expected consumption per EAF dust

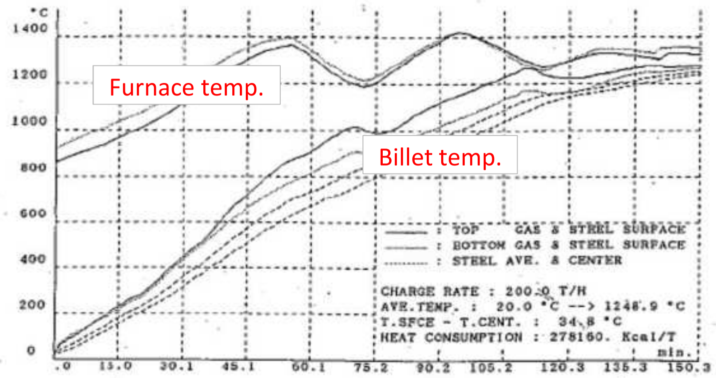
Heavy Oil	160.0	L/t-EAF Dust
Oxygen	390.0	m3N/t-EAF Dust
Waste Plastic	96.0	kg/t-EAF Dust

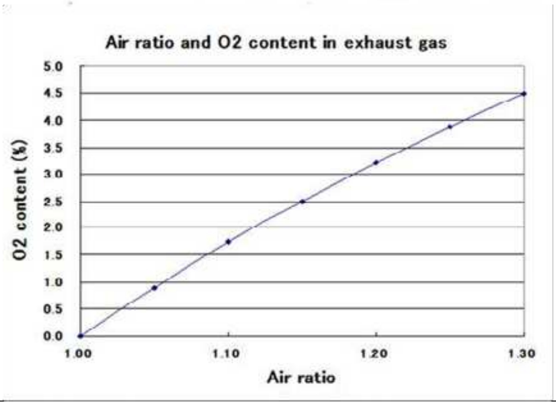
C-2

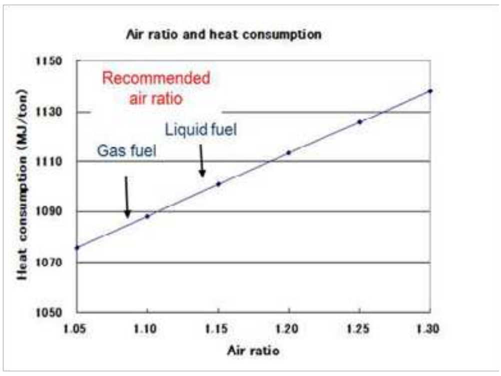
C. Material Recycle for Electric Arc Furnace

EAF slag agglomeration for aggregate use

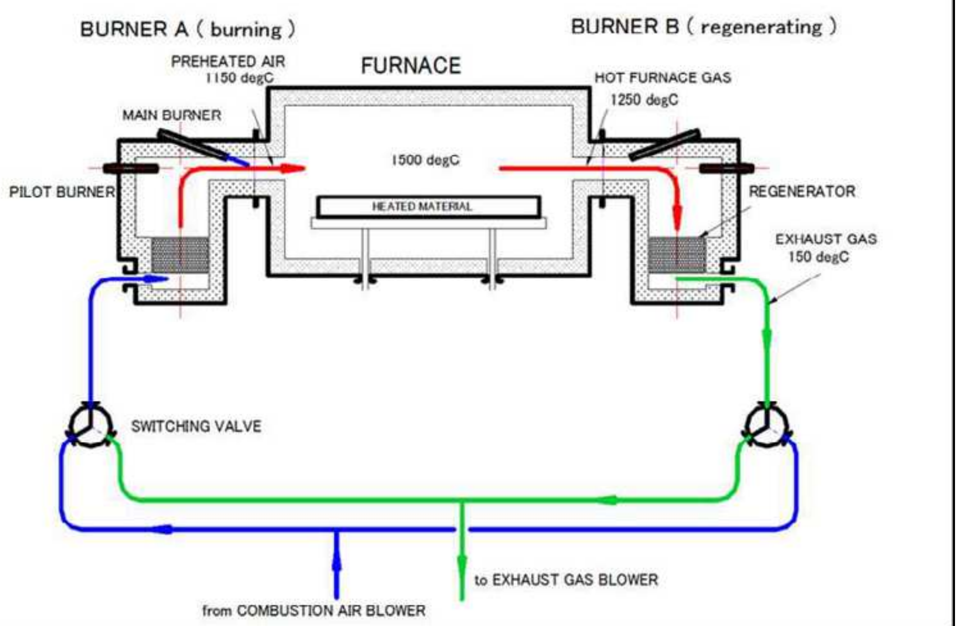
Item		Content
1. Process Flow or Diagram		 ***Treatment Process for Electric Arc Furnace Slag Air*** 
2. Technology Definition/Specification		Molten slag is rapidly cooled by jet air, and becomes 0.3-5mm size of spherical structure, -Create strong & heavy fine aggregate material for concrete -Enviromental friendly material -Suitable & meet with JIS A 5011-4 for Electric arc furnace oxidizing slag aggregate. -Require smaller space than normal slag treatment area.
3. Expected Effect of Technology Introduction	･Electricity Saving	Electricity consumption : 6 - 8 kWh/ton-slag
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	Reduce disposal cost of industrial waste Processing time for one heat of EAF : 10 minutes
4. Japanese Main Supplier		Nikko
5. Technologies Reference		Diagram from Nikko
6. Comments		<Notice> When using this technology, slag analysis data should be confirmed to meet the environmental regulation <Preconditions on calculating effects> - Slag generation : 80 kg/ton-product - Yield of granulated slag with this process : 60-70 %

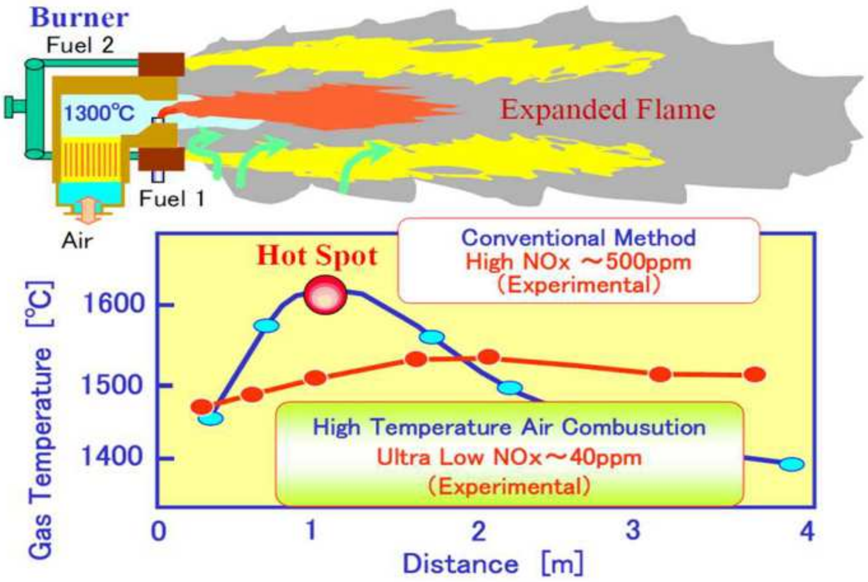
<table>
<tr><td>D-1</td><td colspan="2">D. Energy Saving for Reheating Furnace
Process control for reheating furnace</td></tr>
<tr><th colspan="2">Item</th><th>Content</th></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>






</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>- Setting furnace temperature by targeted billet temperature curve
- Precise air ratio control and O2 analysis in exhaust gas</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>0.05 GJ/ton-product (3.5 % fuel saving from the base line of 1,450 MJ/ton)</td></tr>
<tr><td>･Environmental benefits</td><td>-</td></tr>
<tr><td>･Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro, Rozai Kogyo</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>May contact to Chugai-Ro</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

<table>
<tr><td colspan="2">D-2</td><td>D. Energy Saving for Reheating Furnace
Low NOx regenerative burner total system for reheating furnace</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>


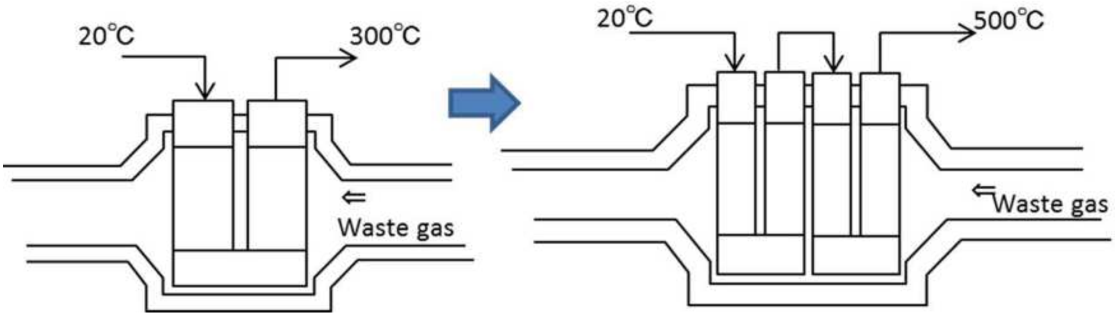
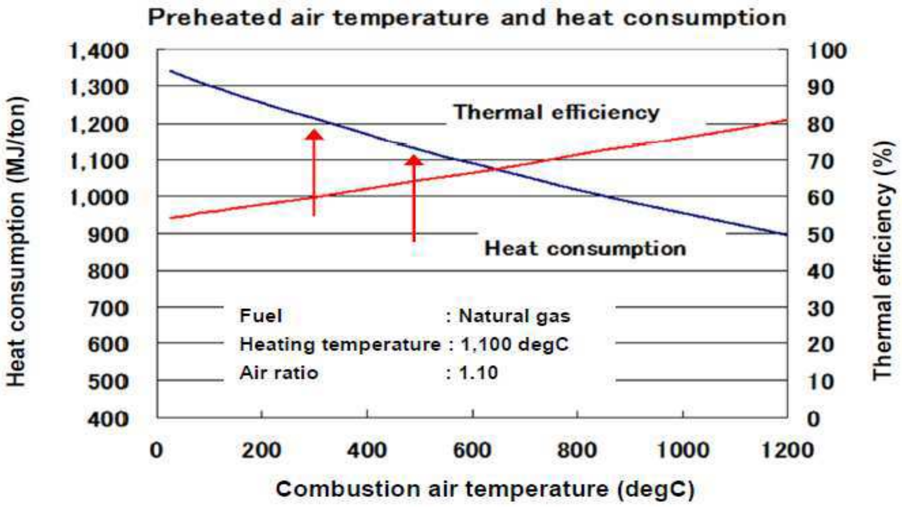


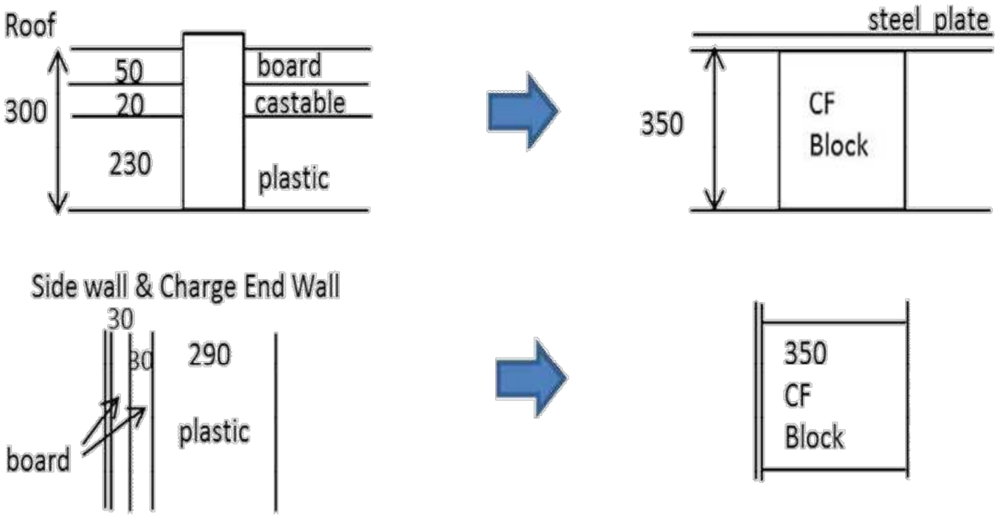
</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>While one of the burners is burning, the other burner will work as an exhaust outlet.
The exhaust gas is discharged from the system after the waste heat of the gas is recovered so that the temperature of the gas will be lowered 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 superhigh temperature (i.e., 90% of the temperature of the exhaust gas or over) before the combustion air is supplied 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>0.189 GJ/t (about -13%)</td></tr>
<tr><td>･Environmental benefits</td><td>CO2 & NOx Reduction</td></tr>
<tr><td>･Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro, Nippon Furnace, Rozai Kogyo</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td>Diagram from Chugai Ro, May contact to suppliers</td></tr>
<tr><td colspan="2">6. Comments</td><td>-</td></tr>
</table>

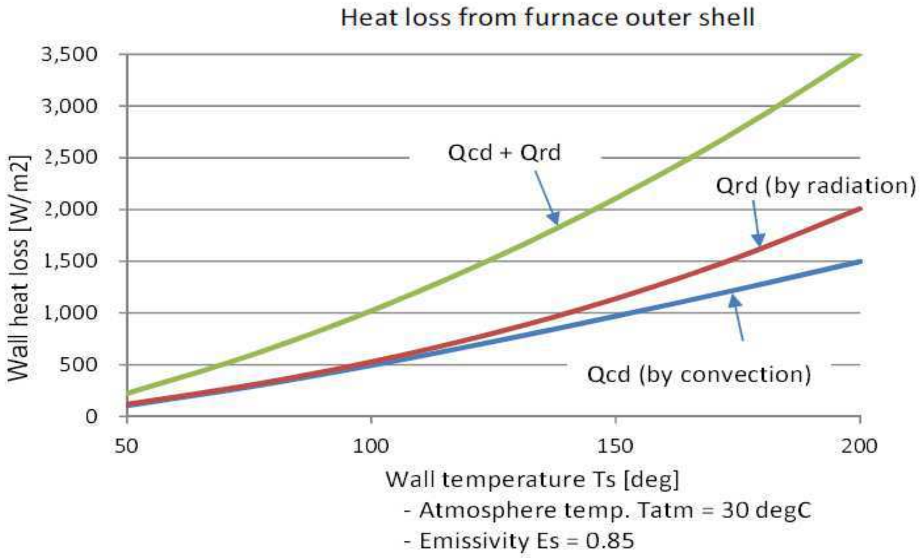
D-3

D. Energy Saving for Reheating Furnace

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, Rozai Kogyo
5. Technologies Reference		Diagram from Chugai Ro
6. Comments		<Preconditions on calculating effects> When 300 degC air temperature is raised to 500 degC, 7 % enrgy saving is expected.

<table>
<tr><td rowspan="2" colspan="2">D-4</td><td>D. Energy Saving for Reheating Furnace</td></tr>
<tr><td>Fiber block for insulation of reheating furnace</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>




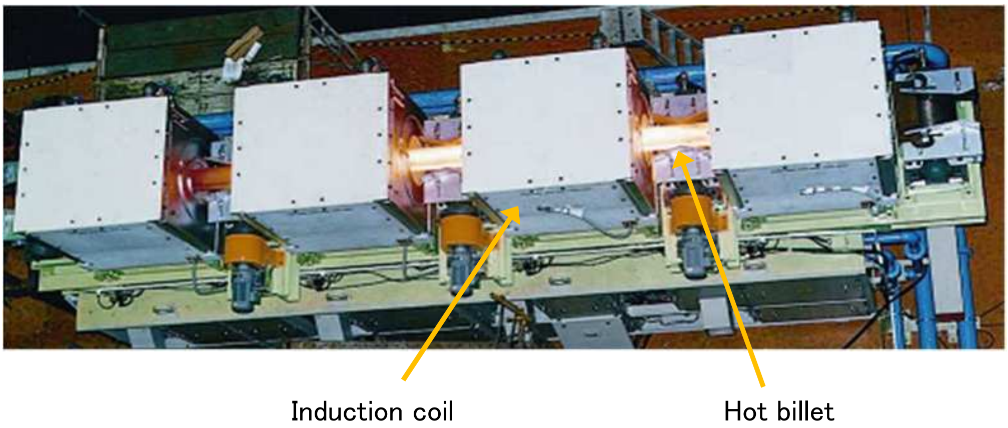
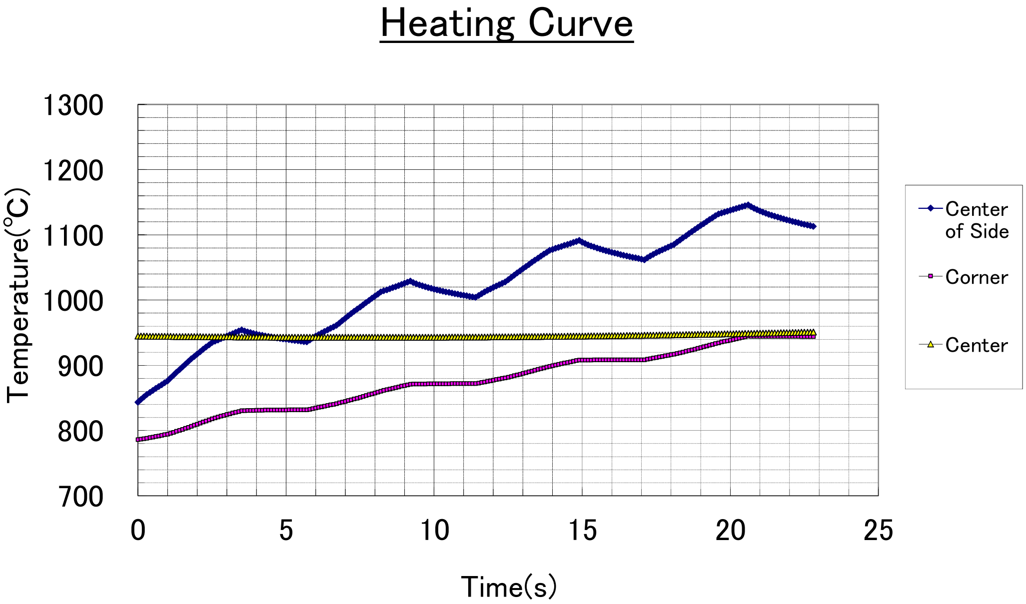
$$Qs = 2.44\times(Ts-Tatm)^{1.25} + 5.674/10^{8}\times\varepsilon_{s}\times((Ts+273.15)^{4}-(Tatm+273.15)^{4} \quad [W/m2]$$

(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 enrgy-saving operation.</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Chugai-Ro, Rozai Kogyo</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>

D-6

D. Energy Saving for Reheating Furnace

Induction type billet heater for direct rolling

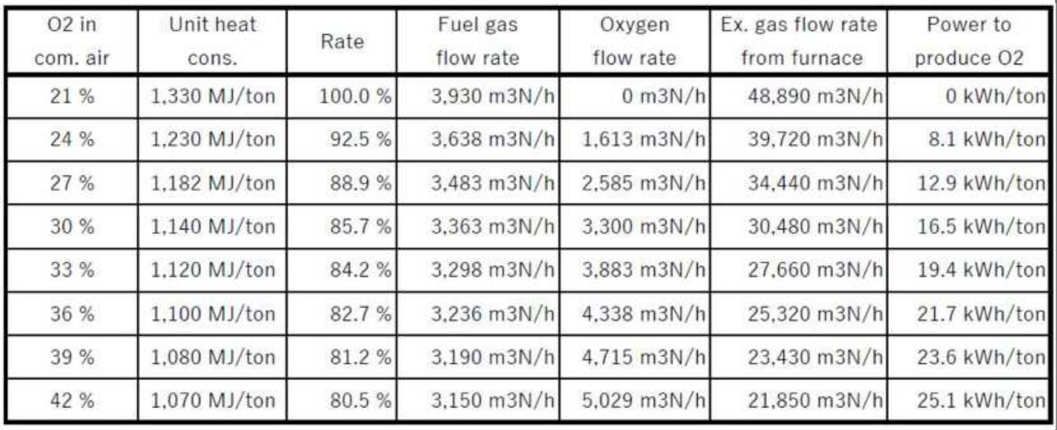
Item		Content
1. Process Flow or Diagram		 
2. Technology Definition/Specification		Compensate temperature drop of billets transferred from CC to rolling mill (from 950 degC to 1050 degC). Advantages : - Automatic control - Less exhaust gas (without reheating furnace)
3. Expected Effect of Technology 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		

D-7

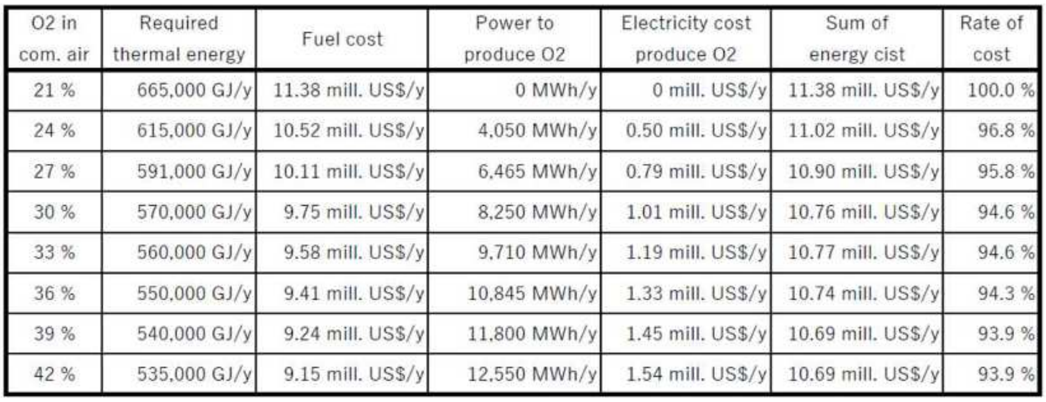
D. Energy Saving for Reheating Furnace

Oxygen enrichment for combusiotn air

Item	Content
1. Process Flow or Diagram	When oxygen is mixed into combusiotn 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, therfore, new equipment for oxygen generation is not considered i n 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 id 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.

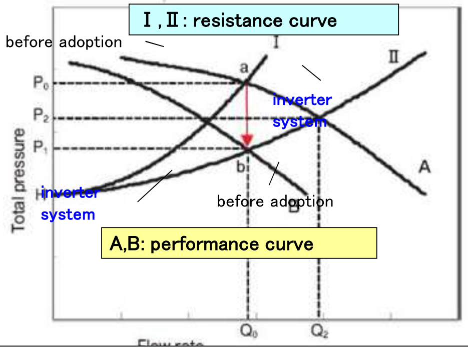
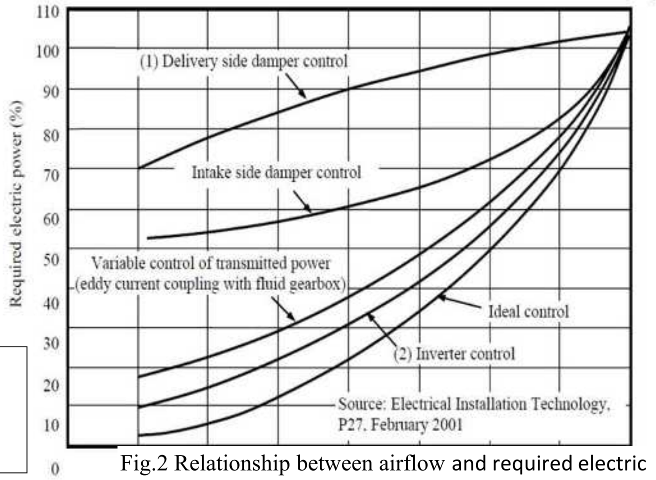


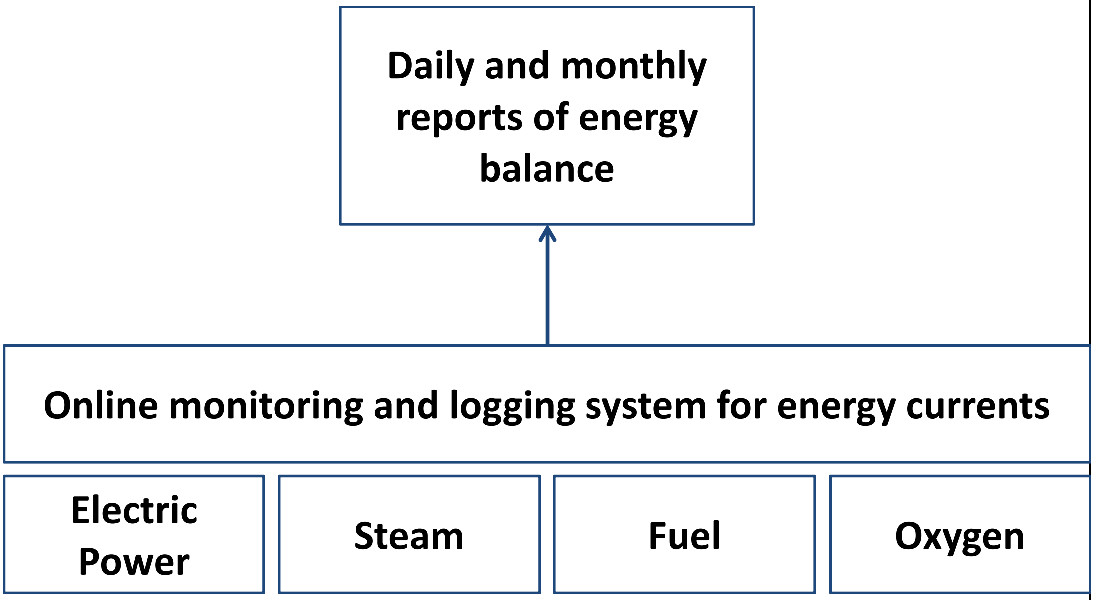
O2 in com. air	Unit heat cons.	Rate	Fuel gas flow rate	Oxygen flow rate	Ex. gas flow rate from furnace	Power to produce O2
21 %	1,330 MJ/ton	100.0 %	3,930 m3N/h	0 m3N/h	48,890 m3N/h	0 kWh/ton
24 %	1,230 MJ/ton	92.5 %	3,638 m3N/h	1,613 m3N/h	39,720 m3N/h	8.1 kWh/ton
27 %	1,182 MJ/ton	88.9 %	3,483 m3N/h	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 %
33 %	560,000 GJ/y	9.58 mill. US$/y	9,710 MWh/y	1.19 mill. US$/y	10.77 mill. US$/y	94.6 %
36 %	550,000 GJ/y	9.41 mill. US$/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 %

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, Rozai Kogyo, Nippon furnace
5. Technologies Reference		
6. Comments		Furnace manufactureres can arrange the oxygen control system and piping revamping.

E-1	E. Common systems and General Energy Savings **Inverter (VVVF; Variable Voltage Valuable Frequency) Drive for Motors**	
Item		**Content**
1. Process Flow or Diagram		 - Pumps are running at point “ a” in the current situation, and will be running at point “ b” after adoption of an inverter system. - Power for pumps is proportional to“ flow rate × total pressure”, and motor input ratio before and after installation is the ratio of Q0 × P1 and Q0 × P0. Fig.1 Relationship between flow rate and total pressure before/after adoption of an inverter system. *1  Source: Electrical Installation Technology, P27, February 2001 Fig.2 Relationship between airflow and required electric power relating to the type of control *2
2. Technology Definition/Specification		* Problems with the current situation: Generally, flow rate of centrifugal pumps and fans is controlled by valves because of uncontollable motor rotaion speed, resulting in great power loss (see Fig.1 I and A). * Improvement measures: An inverter system will be adopted in pumps and fans, in order to control the rotation speed according to the load (flow rate) with valves fully open. This results in electricity savings (see Fig.1 I and A). *1 An inverter is a variable speed device controlling frequency and voltage to allow precise control of rotation. Energy saving effect : Conversion of six 55kW electric motors with eddy current coupling, and reduction in power consumption. *2 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)
3. Investment Cost & Operating Life		￥2,000,000/unit(assumed) [NEDO]
4. Effect of Technology Introduction	･Reduction of CO2 Emission	Not announced
	･Electricity Savings	125,000 kWh/y【=55kW/unit x 0.7(assumed aveerage motor power) x 6units x 3600h/y x 0.15】
5. Direct Effect (Annual Operating Cost)	･Economic Effect (payback time)	1.5 years [NEDO]
	･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		Fuji Electric
9. Technologies Reference:		*1 Guidebook on Energy Conservation for Factories (2010/2011), ed. by The Energy Conservation Center, Japan *2 Energy savings Diagnosis Examples-Common Equipment Volume', Energy conservation Center, Japan
10. Preconditions		* Payback time is defined as (Investment cost / Economical merit) in this project. * annual operation : 3,600 h/y, * unit cost of power : ￥15/kWh

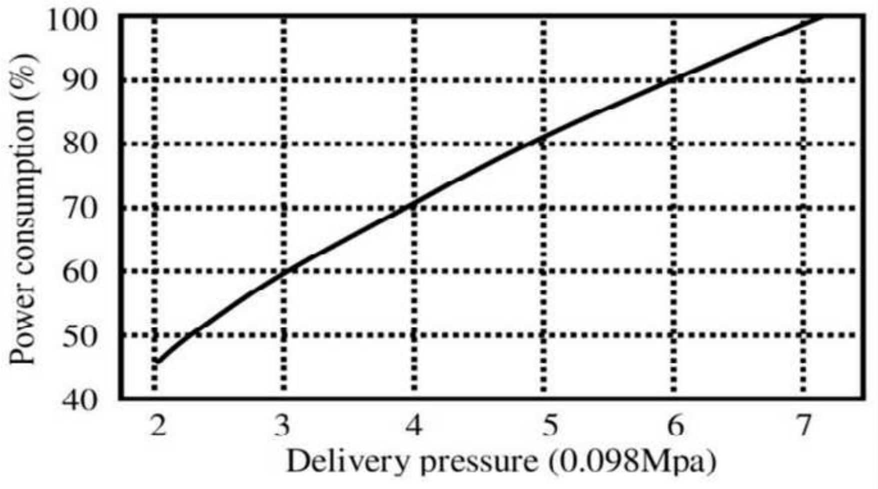
<table>
<tr><td colspan="2" rowspan="2">E-2</td><td>E. Common systems and General Energy Savings</td></tr>
<tr><td>Energy monitoring and management systems</td></tr>
<tr><td colspan="2">Item</td><td>Content</td></tr>
<tr><td colspan="2">1. Process Flow or Diagram</td><td>


</td></tr>
<tr><td colspan="2">2. Technology Definition/Specification</td><td>This measure includes site energy management systems for optimal energy consumption in the plant.
- Online monitoring: This is often used for the most important energy flows at the site. The data are stored for a long time so that typical situations may be analyzed. It is very important to monitor for all energy sources on online. It is the main technique used to avoid energy losses.
- Continuous monitoring systems: Since all energy-related process parameters are used to optimize process control and to enable instant maintenance, undisrupted production process could be achieved.
- 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 enables to compare actual data with historical data (e.g. charts)</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>Energy saving effect depends on the local conditions, therefore, quantitative estimation is difficult.</td></tr>
<tr><td>･Environmental Benefits</td><td>-</td></tr>
<tr><td>･Co-benefits</td><td>-</td></tr>
<tr><td colspan="2">4. Japanese Main Supplier</td><td>Fuji Electric</td></tr>
<tr><td colspan="2">5. Technologies Reference</td><td></td></tr>
<tr><td colspan="2">6. Comments</td><td></td></tr>
</table>

E-3

E. Common systems and General Energy Savings

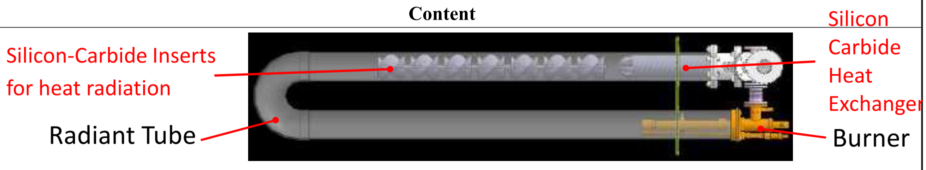
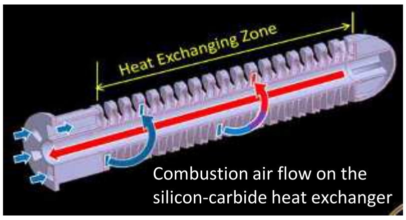
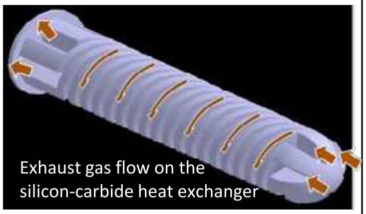
Management of compressed air delivery pressure optimization

Item		Content
1. Process Flow or Diagram		 Relationship Between Delivery Pressure and Power consumption (with fixed delivery capacity)
2. Technology Definition/Specification		Energy saving in compressors requires consideration of the following points. * Selection of the appropriate capacity * Reduction in delivery pressure by keeping the required working power Since the required motive power increases with increased delivery pressure, appropreate delivery pressure should be selected in consideration of the items below. * 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 From the figure above, when delivery pressure is reduced to 0.098MPa, load on the electric motor can be reduced by approximately 10 %. When low pressure air is sufficient, low pressure unit should be addtionally adopted instead of pressure reducing valves.
3. Expected Effect of Technology Introduction	･Electricity Saving	285 MWh/y (=823 kW x 60 % x 10 % x 24 h/d x 241 days/y)
	･Thermal Energy Savings	-
	･Environmental benefits	-
	･Co-benefits	-
4. Japanese Main Supplier		Major electric equipment suppliers
5. Technologies Reference		Japanese Technologies for Energy Savings/GHG Emissions Reduction《2008 Revised Edition》, editted by NEDO
6. Comments		Preconditions for trail calculating above> - Number of compressors; Total of 17, *Delivery pressure; 0.8 MPa, - Equipment capacity; 823 kW, *On-load operation load; 60 %, - Daily operation; 24 h/d, *Annual operation; 241 days'

E-4

E. Common systems and General Energy Savings

Highly efficient combustion system for radiant tube burner

Item		**Content**
1. Process Flow		  Combustion air flow on the silicon-carbide heat exchanger Exhaust gas flow on the silicon-carbide heat exchanger
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.

Contact Points of Suppliers

Company	Contact Points	Technologies
JP Steel Plantech Co.	Kaneko 2nd Building 4-9F 2-6-23 Shin-yokohama, Kohoku-ku, Yokohama 222-0033 JAPAN Phone: +81-45-471-3911 Fax: +81-45-471-4002 https://steelplantech.com/en/	A-1: High temperature continuous scrap preheating EAF A-3: High efficiency oxy-fuel burner/lancing for EAF A-4: Eccentric bottom tapping (EBT) on existing furnace A-5: Ultra high-power transformer for EAF A-6: Optimizing slag foaming in EAF A-7: Optimized power control for EAF A-11: Waste heat recovery from EAF A-12: Energy saving for dedusting system in EAF meltshop B-1: Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF B-2: Floating dust control in EAF meltshop B-4: Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas B-5: Dioxin adsorption by 2 step bagfilter technology for EAF exhaust gas B-6: PKS charcoal use for EAF
Daido Steel Co., Ltd.	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/	A-2: Medium temperature batch scrap preheating EAF A-3: High efficiency oxy-fuel burner/lancing for EAF A-4: Eccentric bottom tapping (EBT) on existing furnace A-5: Ultra high-power transformer for EAF A-6: Optimizing slag foaming in EAF A-8: Operation support system with EAF meltdown judgment A-12: Energy saving for dedusting system in EAF meltshop A-13: Bottom stirring/stirring gas injection A-16: Arc furnace with shell rotation drive B-1: Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF B-2: Floating dust control in EAF meltshop B-4: Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas B-5: Dioxin adsorption by 2 step bagfilter technology for EAF exhaust gas C-1: EAF dust and slag recycling system by oxygen-fuel burner E-4: Highly efficient combustion system for radiant tube burner
Nikko Industry Co., Ltd.	2-4-10, Nunobiki-cho, Chuo-ku, Kobe-city, Hyogo 651-0097. Japan TEL：+81-78-222-1688 FAX：+81-78-222-2916 https://www.nikko-japan.co.jp/home_en/ E-mail：nikko@nikko-japan.co.jp	A-3: High efficiency oxy-fuel burner/lancing for EAF A-4: Eccentric bottom tapping (EBT) on existing furnace A-5: Ultra high-power transformer for EAF A-6: Optimizing slag foaming in EAF A-13: Bottom stirring/stirring gas injection B-1: Exhaust gas treatment through gas cooling, carbon injection, and bag filter dedusting for EAF B-4: Dioxin adsorption by mixing EAF exhaust gas with building dedusting gas B-5: Dioxin adsorption by 2 step bagfilter technology for EAF exhaust gas C-2: EAF slag agglomeration for aggregate use
Chugai Ro Co., Ltd.	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/	A-9: Low NOx regenerative burner system for ladle preheating A-10: Oxygen burner system for ladle preheating D-1: Process control for reheating furnace D-2: Low NOx regenerative burner total system for reheating furnace D-3: High temperature recuperator for reheating furnace D-4: Fiber block for insulation of reheating furnace D-7: Oxygen enrichment for RHF combustion air
Nippon Furnace Co., Ltd.	2-1-53, Shitte, Tsurumi-ku, Yokohama City, Kanagawa Prefecture, 230-8666 Japan TEL.+81-45-575-8111 FAX.+81-45-575-8046 http://www.furnace.co.jp/en.html E-mail.webmaster@furnace.co.jp	A-9: Low NOx regenerative burner system for ladle preheating A-10: Oxygen burner system for ladle preheating D-2: Low NOx regenerative burner total system for reheating furnace D-7: Oxygen enrichment for RHF combustion air
Fuji Electric Co., Ltd.	Gate City Ohsaki, East Tower, 11-2, Osaki 1-chome, Shinagawa-ku, Tokyo 141-0032, Japan https://www.fujielectric.com/contact/?ui_medium=gl_glnav	A-5: Ultra high-power transformer for EAF A-12: Energy saving for dedusting system in EAF meltshop A-14: Induction type tundish heater Ｅ-1: Inverter (VVVF; Variable Voltage Valuable Frequency) Drive for Motors E-2: Energy monitoring and management systems
Fuji Car Manufacturing Co., Ltd.	13-1 Chishiro-cho, Moriyama-city, Shiga, JAPAN 524-0034 TEL +81-77-583-1235 / FAX +81-	A-15: Scrap pretreatment with scrap shear

	77-582-8805 http://www.fujicar.com/ENG_fujicar/	
JFE Engineering Corporation	2-1,Suehiro-cho,Tsurumi-ku,Yokohama 230-8611, JAPAN http://www.jfe-eng.co.jp/en/	B-3: Dioxin adsorption by activated carbon for EAF exhaust gas
Rozai Kogyo Kaisha Ltd.	2-14, Minamihorie 1-chome, Nishi-ku, Osaka, Japan 550-0015 Phone: +81 6-6534-3609 / Fax: +81 6-6534-3602 http://www.rozai.co.jp/en/company/index.html	D-1: Process control for reheating furnace D-2: Low NOx regenerative burner total system for reheating furnace D-3: High temperature recuperator for reheating furnace D-4: Fiber block for insulation of reheating furnace D-7: Oxygen enrichment for RHF combustion air
Mitsui E&S Power Systems Inc.	MESPS Tokyo Office: TEL +81-3-6806-1075 FAX +81-3-5294-1121 https://www.mesps.co.jp/contact/index.html	D-6: Induction type billet heater RHF for direct rolling

ANNEX 1
Used Values and Applied Preconditions

Pre-Conditions for Calculating Electricity and/or Thermal Energy Savings

Capacity and performance of the model steel plant to study costs and effects of energy saving project are assumed as below:

1) 100 % scrap use EFA plant to produce mild steel for construction use
2) Annual production is 500,000 ton/y with 80 ton EAF
3) Unit electricity consumption of EAF is 430 kWh/ton-billet
4) Unit thermal consumption of reheating furnace is 1,450 MJ/ton-billet
5) The plant possesses conventional facilities, without advanced technologies

Equipment List of Model Steel Plant

Annual Production		500,000 ton/year (594,000 ton/year for E-4 only)	
EAF		RHF	
Equipment Name	Value	Equipment Name	Value
Nominal capacity	80 ton	Type	Walking beam
TTT	52 minutes	Nominal capacity	100 ton/h
Iron source	100 % scrap	Heated material	135 SQ billet
Scrap preheating	none	Heating temperature	1100 degC
Scrap charging	3 times	Fuel	Natural gas, LHV 44 MJ/m3N
Ladle furnace	used	Combustion air preheating	around 300 degC with low grade recuperator
NG burner	used only to facilitate melting	Air ratio for combustion	1.20 for all zones
O2 and C lances	installed only at slag-door side, water-cooled type	Computer control to set furnace temperature with heat transfer simulation	none
Process control by exhaust gas analysis and/or computer	none	Hot charge and/or direct rolling	none
Electricity consumption	430 kWh/ton	Insulation	firebrick
Oxygen consumption	30 m3N/ton	Heat consumption	1,330 MJ/ton-steel
Natural gas consumption	20 m3N/ton		
Coke consumption	15 kg/ton		
Product	Mild steel less than 0.2 % C		
Tapping temperature	1620 degC		
Atmosphere condition	25 degC with relative humidity 60 %		

Pre-Conditions for Calculating the profit, assumed investment cost, payback time and CO2 emission reductions

1) For calculating the profit, assumed investment cost and payback time for each technologies listed on the Technologies Customized List, the values shown on the table "Energy price, plant cost, and CO2 emission factor in India" were applied.
2) The assumed investment cost in India for each technology is calculated by multiplying "plant cost index" to the assumed investment cost in Japan.
3) CO2 emission reduction is calculated for each technology by using emission factor of electricity in India and the common value of CO2 emission rate from fuel (63.1 kg-CO2/GJ).

Energy price, plant cost, and CO2 emission factor in India

Country	Electricity price for industry use 1) (US$/kWh)	Fuel gas price for industry use 1) (US$/GJ)	Plant cost index2) (Japan = 100.0)	CO2 emission factor 3) (ton-CO2/MWh)
India	0.100	18.73	72.9	0.905
Japan (for reference)	0.143	19.11	100.0	0.434 4)

Source 1) JETRO website (2021)
2) 2019PCI_LF_summary.pdf, Japan Machinery Center for Trade and Investment
3) average of combined margin from CDM projects, IGES website (2021.2.23)
4) Tokyo Electric Power Company website (2021)