THE MOST ADVANCED POWER SAVING TECHNOLOGY IN EAF INTRODUCTION TO ECOARC™

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1 ABSTRACT

The steel industry is one of the largest energy consumers in industrial countries.
Electric arc furnaces (hereinafter referred to as “EAF”) use more energy than any other equipment within the Mini-Mill industry. Improving the energy efficiency of EAF, therefore, is a priority of the Mini-Mill industry.
Based on this philosophy, JP Steel Plantech Co. (hereinafter referred to as “SPCO”) has developed “ECOARC™”, a high efficiency EAF that represents the most advanced and proven energy recovery and environmentally conscious technology in the industry. ECOARC™ uses high temperature exhaust gas in a scrap preheating shaft attached directly to the furnace shell to preheat scrap without oxidization of scrap. And after that, the exhaust gas is used to treat unwanted chemicals from the waste gas in combustion chamber without the use of extra fuel. Only ECOARC™ can achieve these features because it has high level air tightness to prevent air infiltration into its furnace shell and scrap preheating shaft.
Already Five ECOARC™s are in operation as a commercial EAF in Japan, South Korea and Thailand which have achieved approx. 30 % reduction of energy. The latest commercial ECOARC™ is in Thailand and was started up in 2012. It took only two months after its start-up to achieve targets.
In our paper, we will describe the method of improving energy efficiency by the utilization of waste heat in the off gas generated in EAF and introduce ECOARC™s under commercial operation.

Keywords: EAF, ECOARC™, Electric Arc Furnace, Off Gas, High Efficiency, Scrap Preheating

2 INTRODUCTION

Recently, most industries are emphasizing in lower energy consumption and low emissions not only in industrially advanced nations but in developing nations too, to prevent global warming.

Since the steel industry is one of the largest share in energy consumption, so it is effective and desirable to reduce its energy consumptions. Electric arc furnaces(EAF) use more energy than any other equipment except blast furnace in the steel industry. Improving the energy efficiency of EAF, therefore, is a priority.

Accordingly, JP Steel Plantech Co(SPCO) has developed “ECOARC™”, a revolutionary EAF that represents the most advanced energy recovery and environmentally conscious EAF technology in the steelmaking industry. In Japan and Korea, so far four ECOARC™ are operating smoothly commercially. Also in Thailand, fifth ECOARC™ was installed in UMC Metals Ltd.(UMC) and it was started up successfully in November 2012.

In this project, a lot of existing facilities were reused except key components of ECOARC™ technology such as scrap preheating shaft, furnace shell, direct off-gas treatment and scrap handling system to minimize initial cost and construction period.

In this paper, outline of ECOARC™ is explained in brief firstly and then outline and operation results of the UMC project are mainly described.

3 OUTLINE of ECOARC™

3.1 Concept of the furnace

Figure 1 shows the concept diagram of ECOARC™. It consists of a melting chamber along with a preheating shaft, which are directly and rigidly connected together.

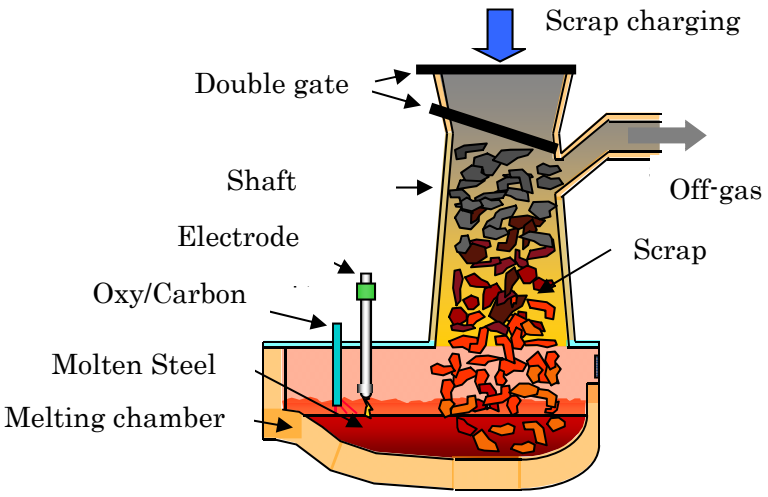


Figure 1. Concept diagram of ECOARC™

As the result, the shaft and chamber tilts together. As the connection is tight, there is no air infiltration to the preheating shaft. Also, the opening within panels etc. in the melting chamber is minimized and semi-air tight configuration is realized. Oxygen and carbon lances

are attached for slag foaming and molten steel carbon control. The scrap is fed to the furnace from the top of the shaft to maintain certain scrap level in the shaft.

Except cold start, the melting process proceeds under flat bath condition. Scrap level in the shaft is maintained throughout the heat cycle as a result scrap at the bottom of the shaft is always in contact with the molten steel present in the melting chamber. Again, scrap is supplied to the shaft when the scrap level is lowered due to melting process in the melting chamber.

After melting one heat amount of steel, the scrap feeding is stopped. Operation is shifted to super heating period along with the not melted scrap remaining in the shaft itself, and then molten steel is tapped after getting predetermined steel temperature.

3.2 Concept of ECOARC™ off-gas treatment system

Figure 2 shows the flow of off-gas from the preheating shaft. The generation of harmful chemicals can be avoided by marginally increasing the amount of fuel used. In ECOARC™, the oxidation level (OD=CO2/{CO+CO2}) of the off-gas from the preheating shaft is controlled from 60 to 70%, which enables the combustion to take place by addition of CO in the off-gas itself. The off-gas under goes combustion in the combustion chamber, which is located downstream from the preheating shaft, and is maintained at a sufficiently high temperature and time for dioxins to be easily decomposed. After combustion, the gas is rapidly cooled by a direct water spray cooling system in the spray cooling chamber, which prevents the re-composition of dioxins. Through this process of off-gas treatment, ECOARC™ has met actual dioxin content levels of less than 0.5 ng-TEQ/m3N, which meets Japanese regulations for new electric arc furnaces.

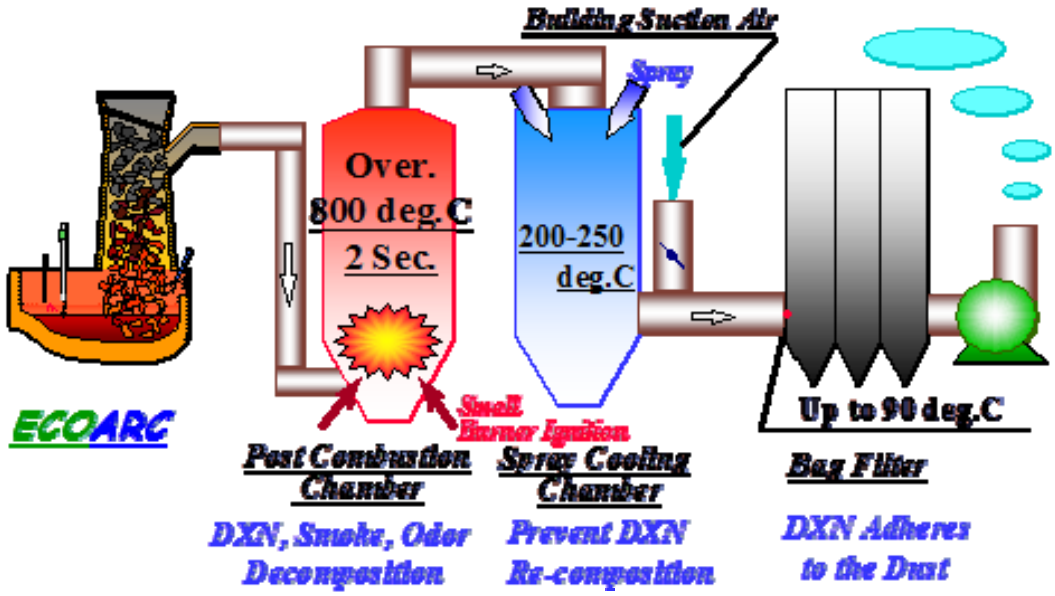


Figure 2. ECOARC™ pollutant treatment system

3.3 Commercial application of ECOARC™

Table 1 shows the main specification of ECOARC™, out of which five are operating smoothly, except the sixth one which is under erection stage.

Table 1. Main specification of commercial ECOARC™

NO	1	2	3	4	5	6*
Startup year	2001	2005	2008	2010	2012	2014
Country	Japan	Japan	Japan	Korea	Thailand	Japan
Heat size	70 ton	140 ton	130 ton	120 ton	70 ton	200 ton
Furnace Type	AC	AC	AC	AC	AC	AC
Trans Capacity	41 MVA (Reuse)	88 MVA (Reuse)	75 MVA (New)	80 MVA (New)	50MVA (Reuse)	115MVA (New)
Electrode	20 in	24 in	24 in	22 in	22 in	28 in
Product	D-Bar	H-beam, FB, Angle	Rod/Wire For Automobile	D-Bar	D-Bar Billet	Long Products, D-Bar

*Under construction at Feb. 2014

4 PROJECT OUTLINE

4.1 Introduction

UMC Metals Ltd., namely known as UMC is a steel mill in Thailand that has a 70-ton EAF, ladle furnace and a continuous caster. The specifications of main equipment before revamping are shown in below.

Table 2. Specification of main equipment before revamping

Process	Equipment	Specification
Electric arc furnace (EAF)	Type, Capacity	AC 70 tons, EBT
	Transformer	50 MVA
	Oxygen Injector	Water cooled lance
Ladle Furnace (LF)	Capacity	70 tons
	Transformer	10 MVA
Fume Suction System	Building Suction	20,000m^3/min

4.2 Concept of revamped plant

The Thailand ECOARC™ project was initiated with an aim to improve the EAF performance and environmental condition of the surrounding area with a minimum shutdown period for installation of ECOARC™ with its auxiliary equipment, direct fume suction system and

scrap handling system while reusing the existing meltshop facilities as much as possible. The improved target figures were achieved just within two months of hot-run. Secondly as far as reuse of existing facilities was concerned, there was no modification of the overhead crane. Although there were speculations in beginning from customer side that the meltshop building has to be modified as because the ECOARC™ consists of a vertical shaft along with an automatic scrap feeding system which feeds the scrap from the top of the shaft. But finally there were no such modifications required to Melt shop facilities due to ease in ECOARC design. Also, the existing main power system including the furnace transformer, building fume suction system with bag filters, water treatment systems and some other auxiliary facilities were comfortably reused. Details of which shall be explained in the later section of this paper.

4.3 Equipment configuration

To erect ECOARC™, the former EAF's, direct off-gas treatment system and part of the water cooled duct leading to the combustion chamber were removed and the new EAF, off-gas treatment system and auxiliary equipment were installed. Keeping the existing transformer and electrode lifting system as it is. The former scrap bucket was replaced by a smaller one for start heat.

Outline of equipment after installing ECOARC™ can be seen below.

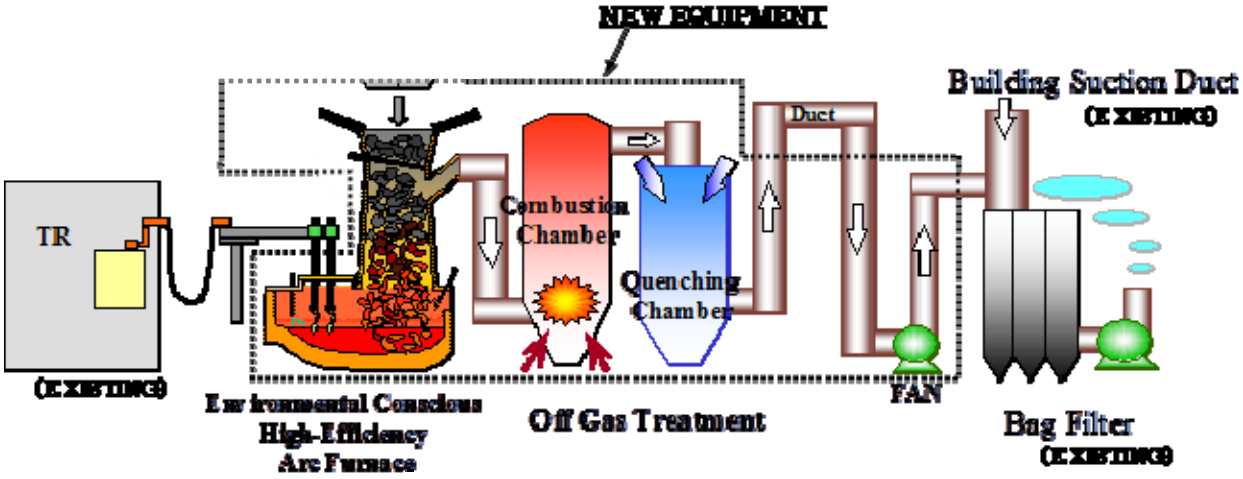


Figure 3. Equipment configuration for ECOARC™

4.4 Effective reuse of existing facilities

To save cost and shutdown time, many facilities were reused as shown in table 3. The ways to reuse old facilities are as followings:

Table 3. Distinction of new and reuse equipment

Item	Status
Building	Reuse
Foundation	Reuse & Partially New
Scrap Charging Crane	Reuse
Scrap Bucket	New
Transformer	Reuse
Building Suction System	Reuse
Direct Suction Booster Fan	New
Bag Filter	Reuse
Water Treatment System	Reuse
Hydraulic System	Reuse & Partially New
Electrode Positioning & Swing System	Reuse

(1) **Building and Foundation**

As reference to brown field project, the first and second commercial ECOARC™ projects reused the existing meltshop building and foundation with partial modification. In case of UMC project, the same above principle was employed in which the existing building was reused without modification and the foundation was reused with partial modifications.

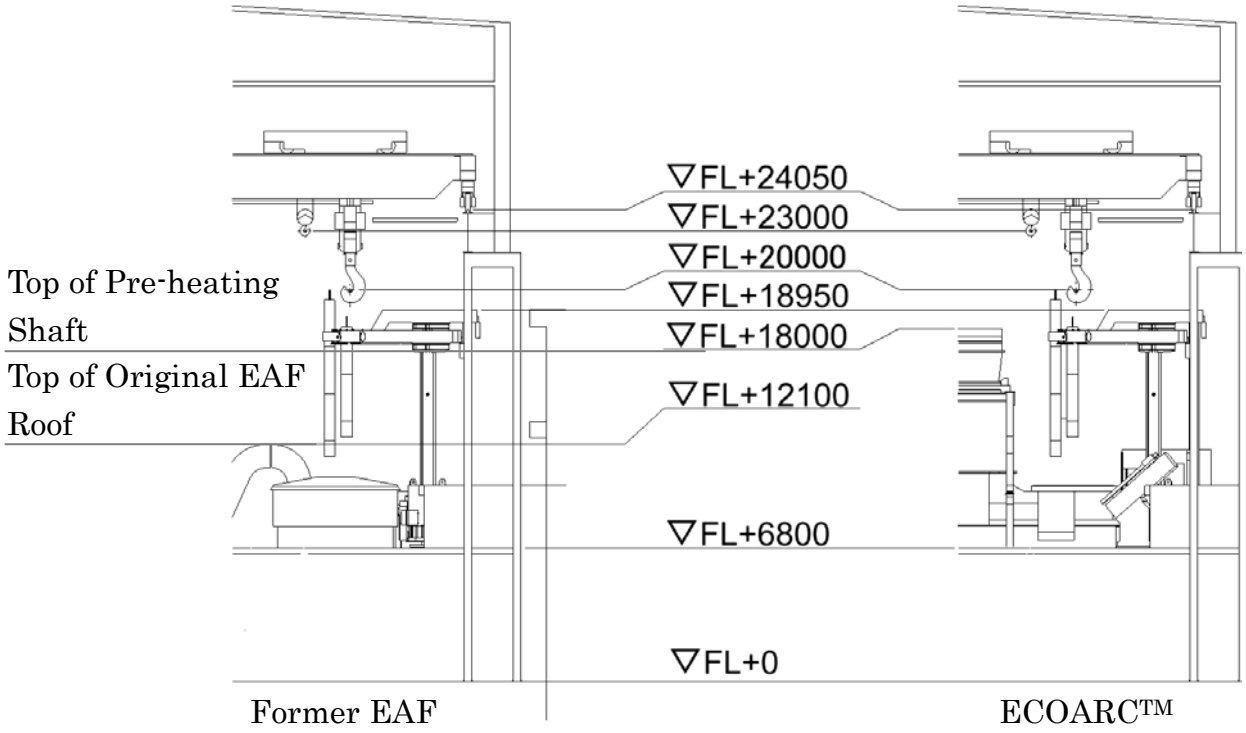


Figure 4. Comparison Between former EAF and ECOARC™

Figure 4 shows comparison between the former furnace and ECOARC™.

In general, a shaft type furnace requires higher meltshop building depending on required

shaft height and scrap charging method. In case of ECOARC™, however,

1) The shaft and the melting chamber are connected directly and the total height of the furnace is much lower than other types of shaft furnaces.
2) Due to scrap charging system with a skip car, top of the shaft can be maintained below travelling elevation of a charging crane in typical meltshop building.

Because of the above characteristics of ECOARC™, meltshop building height can be lower than other types of shaft furnaces, which ultimately minimizes modification of the existing facilities.

(2) **Scrap Charging Crane**

In a conventional furnace, scrap charging is done a few times a heat with a scrap bucket. It is one of the most risky work in operation related to conventional furnace and it causes deterioration in working environment by causing flame, dust, metal splash, etc. during scrap charging In case of ECOARC™, scrap is charged into the shaft with a skip car automatically and no scrap charging crane operation is necessary. As it is not necessary to open the roof for scrap charging, there are no flame nor dust emission by scrap charging and environmental condition around the furnace is good. Therefore, the scrap charging crane is only used for maintenance work and can be reused after revamping into ECOARC™.

(3) **Transformer**

As ECOARC™ can reduce great amount of electrical energy consumption, transformer capacity required can be much smaller when replacing a conventional EAF with the same productivity. The first commercial ECOARC™ shown in Table 1 replaced two 70-ton conventional EAFs keeping the same productivity with one 70-ton ECOARC™. The UMC project also reused the original transformer. This shows it is possible to minimize the investment cost automatically by reusing the existing transformer while achieving higher productivity by replacing a conventional EAF with ECOARC™.

(4) **Building suction system**

Due to air tight construction of ECOARC™ which prevents air infiltration, it is possible to minimize direct suction gas volume. In addition, as there is no scrap charging with roof opening, dust scattered around the furnace is less and dust concentration in the secondary suction gas is also less. Therefore, the existing building suction system can also be reused. Moreover, in the UMC project, only two of the previous three main fans(in tally 20,000m3/min.), which were all running before revamping, are now enough for operation with ECOARC™ due to improvement of working environment.

4.6 SHORT SHUTDOWN PERIOD

In spite of brown field project, installation and cold run test was finished smoothly. The reasons why it could be achieved so efficiently are as follows:

(1) **Attentive meeting with UMC**

With cooperation of UMC, sufficient consultation about scope, design, transportation and schedule etc. could be held before SPCO stay in UMC site and no critical oversight was witnessed. Also during the stay, we kept close with UMC personals and solved problems before they could worsen.

(2) **Full 3D CAD design**

All equipment including reused facilities were modeled in 3D CAD and side by side all interference between facilities was taken care. Also ease of transportation and assembly was achieved through 3D CAD. And hence no problem was detected during erection and cold commissioning.

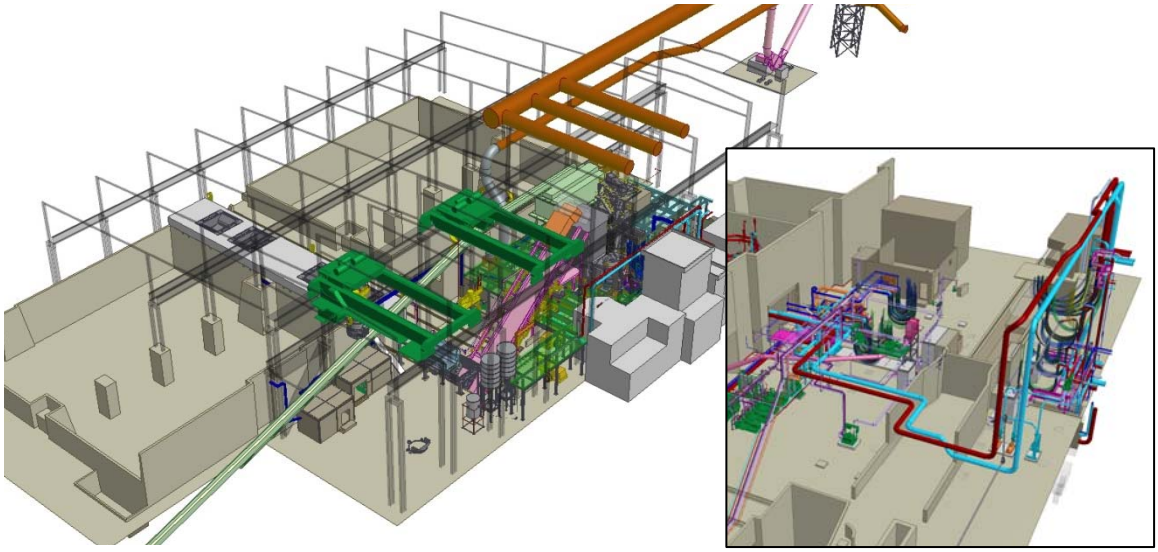


Figure 5. Overall view of meltshop and piping in 3D CAD

5 OPERATION RESULT

After the hot run, operation went smoothly and the performance verification test was successfully conducted in January, 2013. The result was achieved successfully by high reliability/operational ease of ECOARC™ and all UMC's efforts to obtain required operation skills in a short time. The test results are shown in the Table 4 below.

Table 4. ECOARC™ test result in Jan. 2013

ITEM	Former EAF	ECOARC™
Electric Power Consumption [kWh/tbs*]	389	285
Fuel(LPG) Consumption [kg/tbs*]	3.5	1.4
Scrap to Billet Yield [%]	88.4	89.2

*billet weight ton

As shown in the Table 4, the specific electric power consumption has been reduced by more than 100kWh/tbs from the former conventional EAF. The scrap-to-billet yield has even increased by about 0.8% though it is likely to decrease in case of scrap preheating system. Recently, in addition, some trials to use large amount of shredded scrap and to mix HBI in the raw material are exercised and it proves that various kinds of scrap can be used for ECOARC™. The following Table 5 shows improvements in environmental performance obtained at UMC.

Table 5. ECOARC™ environmental performance

No.	ITEM	Former EAF (Oct.3.2011)	ECOARC™ (Dec.16.2012)	REMARKS
1	Dust from Baghouse (Baghouse Inlet) [mg/m^3]	617	437.4	
2	Dust in Respirable Air Around Furnace Area [mg/m^3]	2.7	<0.6	Standard = 5
3	Sound Level Average around Furnace Area [db(A)]	100	87.1	Standard = 90
4	WBGT* Average around Furnace Area [degC]	28.5	28	Standard = 32
5	Dust/Billet [%/ton-Billet]	1.78	0.84	
6	Slag/Billet [%/ton-Billet]	15.52	13.20	

*WBGT: Wet Bulb Globe Temperature

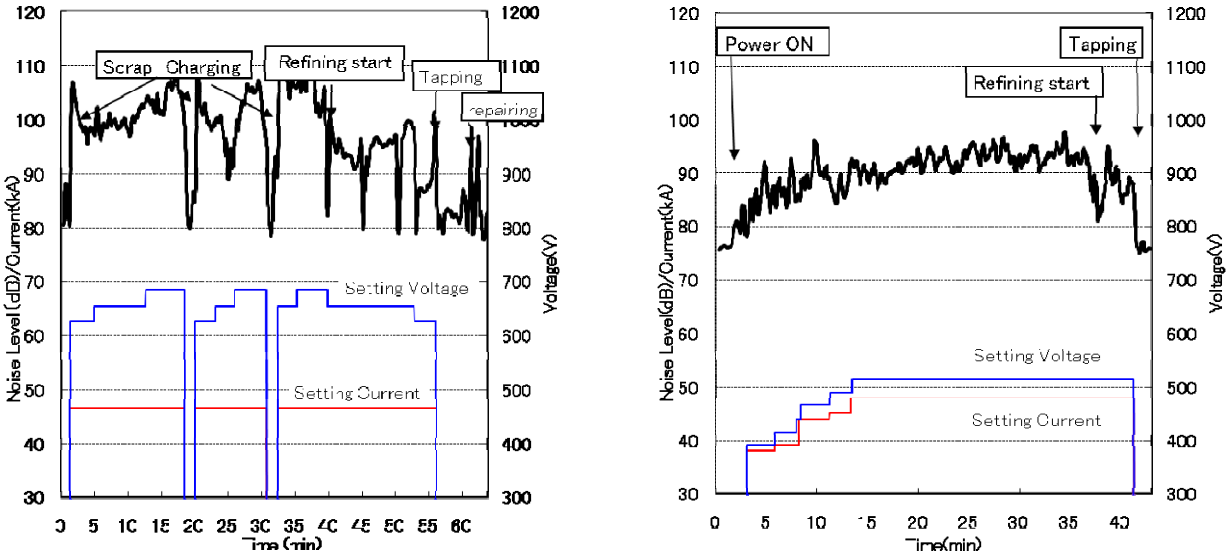
As shown in the table above, ECOARC™ shows lower figures in all the evaluation items.

(1) **Dust Reduction**

In case of ECOARC™, dust generated in the melting chamber is partially caught by scrap when sucked through the preheating shaft and it comes back to the melting chamber. By repeating this process, dust concentration in the direct off-gas is reduced.

(2) **Environment around furnace**

Environmental condition around the furnace is improved compared to a conventional EAF. In case of ECOARC™, scrap is charged through the shaft and it is not necessary to open the roof, which reduces dust around the furnace. Noise around the furnace is significantly reduced too as ECOARC™ is operated under flat bath and sub-merged arc condition by foamy slag. The following figure 6 shows comparison of noise level measurement between a typical conventional furnace and another ECOARC™.



Conventional EAF ECOARC™

Figure 6. Comparing noise level of Conventional EAF and ECOARC™

In our experience with all other ECOARC™s in the past projects, environmental condition around the furnace has been greatly improved compared to the original conventional furnace in UMC. Especially in the UMC project, the performance targets were achieved in a short time and working environment has been improved as well. This is not only improvement of working environment but also reduction of dust treatment/slag disposal work and harmful emissions to surrounding of the steel plant and it leads to reduction of countermeasure cost for environment preservation.

6 CONCLUSION

SPCO has developed high efficiency EAF named ECOARC™ and has five commercial references. Moreover, all of them have achieved huge power saving and in the latest project in Thailand, in spite of minimum investment cost and short-time brown-field revamping project by reusing a lot of the existing facilities, UMC and SPCO successfully started up the first ECOARC™ in Thailand and achieved the performance targets as shown below within two (2) months.

Electric Power Consumption: 285[kWh/tbs]
Fuel(LPG) Consumption: 1.4[kg/tbs]
Billet Yield: 89.2[%]

In addition, improvement of environmental condition such as reduction of dust generation, noise level, etc. by the introduction of ECOARC™ has been confirmed.

It certainly proves that ECOARC™ is a very effective solution to meet the requirements for energy saving and environment protection demanded from all over the world.