Realization of the coexistence of energy saving and environmental measure in the EAF - Concept of ECOARC™ -

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SYNOPSIS

Effective usage of energy has been one of the most important issues for EAF as the biggest energy consumer in the Mini-Mill industry. In addition, the environmental measures have become the most important problem, but the coexistence with environmental measures is difficult because of the conventional scrap preheating system. Against this background, JP Steel Plantech Co. (SPCO) has introduced a new energy saving furnace, called "ECOARC™."

The mechanism of larger energy recovery (a 30% reduction), and technology to facilitate its coexistence with the environmental measures of ECOARC™ are explained, and some actual operation results of the commercial ECOARC™ are presented.

1. Introduction

Recently, high efficiency Arc furnaces have been proposed which utilize the exhaust gas energy to preheat scrap. Some have put into commercial operation. These arc furnaces each consume approx 30 - 35 m^3_N/t of oxygen and it is said that the power consumption level is approx. 280 kWh/t as the best performance.

JP Steel Plantech has developed a new generation high efficiency arc furnace since 1997, whose target of power consumption is less than 200 kWh/t. Based on the successful result of a 5 ton pilot plant, JP Steel Plantech has received the first commercial plant order of "ECOARC™" from Kishiwada Steel Co. Ltd. Afterwards, we have received two in Japan and one in Korea, and four plants are operating smoothly now.

ECOARC™ has various merits such as pollution free, easy operation, labor saving, and etc. In this paper, mainly the power saving technology of the ECOARC™ will be introduced.

2. History of Power Saving technology in EAF Field

In the EAF field, power saving and scrap preheating is synonym in a sense. Various technologies have been developed to effectively and practically preheat the scrap by the exhaust gas, which unfortunately resulted to rise their own issues, reliability, pollution, scrap restriction and etc.

One of the oldest technology to utilize the off gas energy was the so-called scrap pre-heater. This system is to locate a chamber between drop out chamber and a bag house to locate a scrap bucket. The preheat effect was said to be approx. 30 kWh/t at maximum. It is dying technology because of the generation of odor and white smoke.

Another technology is to use slip-stick conveyor to supply scrap to the furnace continuously from the side hole of the furnace shell. The off gas is lead to this conveyor to preheat the scrap in the conveyor. Figure.1 shows this system.

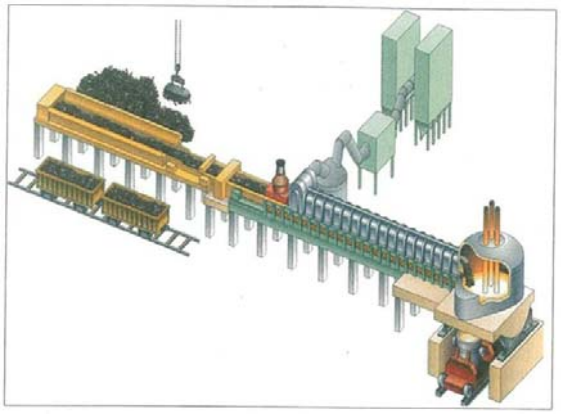

Figure.1 Concept diagram of conveyor type scrap pre-heater [1]

As the arc always strike against the molten steel, this system has a potential to decrease flicker and electrode consumption. On the other hand, only top surface of the scrap can exchange the heat with the off gas, the energy recovery is limited.

The existing shaft furnace comes from the idea to improve the thermal efficiency of the scrap pre-heater. The shaft is located right above the furnace, the melting chamber, and the off gas runs through the shaft exchanging the heat with scrap. The scrap pre-heat effect is larger than the scrap pre-heater, though this is still a batch furnace and the scrap cannot be preheated evenly to the high temperature. Only the bottom part of the charge can be preheated to high temperature, there is a limitation to heat recovery. Figure.2 shows the shaft type pre-heater.

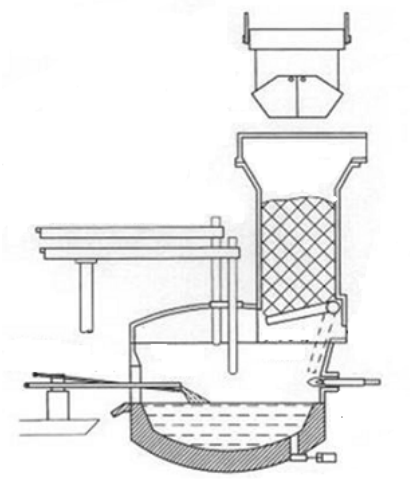

Figure.2 Concept diagram of shaft type scrap pre-heater

One of the issues of this system is the scrap support to isolate the scrap from the melting chamber. The reliability of the scrap support and limitation to the oxygen usage exists to protect the support mechanism from thermal load. Also, the shaft and the melting chamber are divided, a gap between the two is unavoidable. Air infiltration from the gap results in scrap oxidation in the shaft, decrease of melting yield and increase of refractory consumption.

The off gas leaving the shaft is not high enough to thermally decompose the white smoke and odor and these pollution control is another issue of this system.

In this report, we would like to introduce our brand new scrap preheating technology, ECOARC^{TM}. ECOARC^{TM} extremely improves the thermal efficiency and, at the same time, solves various issues of scrap preheating such as over oxidation of scrap, pollution such as dioxins, white smoke and odor. Its unique melting process enables elimination of scrap support mechanism which is one of the equipment drawback issue of existing technology.

3. What is ECOARC^{TM}?

3.1 Outline of Furnace and Operation

Figure.3 shows the concept diagram of ECOARC^{TM}, and Figure.4 shows the outline of the ECOARC^{TM} process. ECOARC^{TM} consists of a melting chamber and a preheating shaft, which are directly and rigidly connected together. The direct evacuation line is consisted with a combustion chamber and a direct spray cooling chamber to thermally decompose pollutants and avoid re-composition of the worst pollutant Dioxins.

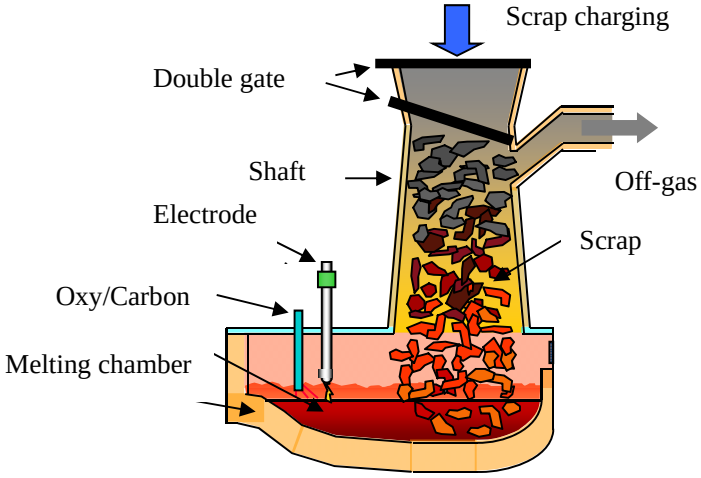

Figure.3 Concept diagram of ECOARC™

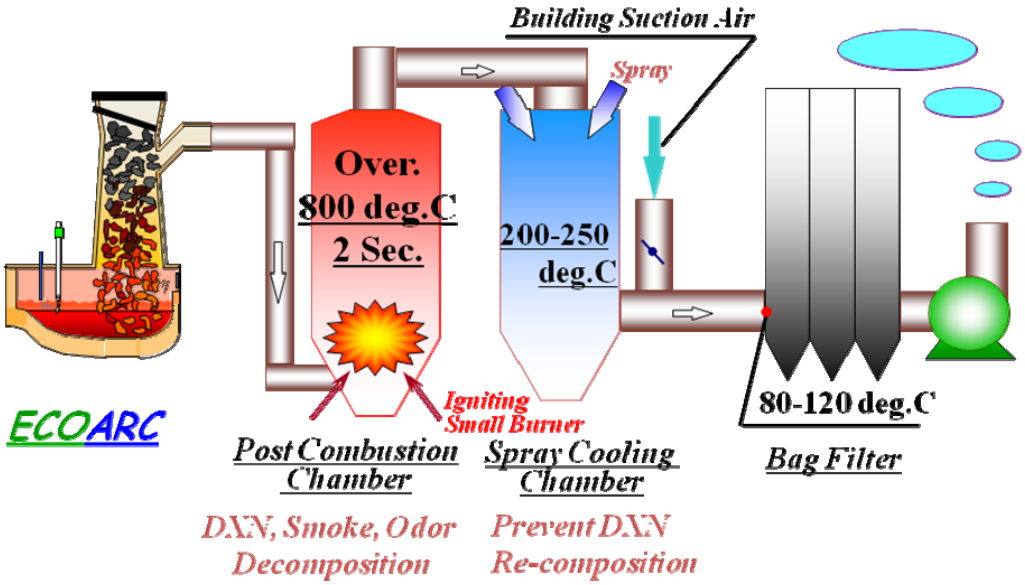

Figure.4 Outline of the ECOARC™ Process

As the preheating shaft and the melting chamber are directly and rigidly connected, the whole shaft and chamber tilts altogether. As the connection is tight, there is no air infiltration to the preheating shaft. Also, the opening of 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 shaft from the top to maintain certain scrap level in the shaft.

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

After melting one heat amount of molten steel, the scrap feeding is stopped. Operation is shifted to super heating period in the

state that a scrap is filled up with in the shaft, and then molten steel is tapped after getting predetermined steel temperature.

3.2 Feature of ECOARC^{TM}

The melting process of the ECOARC^{TM}, which has features of monolithic structure of the shaft and the melting chamber, flat bath operation, the shaft filled with scrap throughout a heat, realizes outstanding operating merits as follows.

Energy Saving

(1) High efficiency

In the ECOARC^{TM} process, high temperature CO and CO_2 gas directly contacts the scrap at the bottom of the shaft without being cooled by water-cooled ducts, panels and scrap support mechanism like a finger. The CO and CO_2 gas is generated in the melting chamber through oxygen lancing, carbon injection for slag foaming and some infiltration air. Data obtained through the operation show that power consumption of 210 kWh/t (t represents metric tons in this paper) can be achieved under the following condition;

Oxygen unit consumption; 33 m^3_N /t

Power consumption; 210 kWh/t

In other scrap preheating process described above, certain distance exists between the scrap preheating vessel and the melting chamber. This distance results in lower off gas temperature before contacting the scrap, limiting the power consumption level to 280 kWh/t in other preheating processes.

(2) Higher amount of oxygen can be used

As described before, the shaft and the melting chamber are directly connected in the ECOARC^{TM} and bottom of the scrap in the shaft is in contact condition with the molten steel. There is no scrap support mechanism to separate the molten steel and scrap within the off gas stream. This results in no limitation of the off gas temperature, which means oxygen usage can be increased compared to other processes and achieves higher scrap preheat temperature.

In other processes, scrap support mechanism or scrap supply equipment is necessary as the preheating chamber and the melting chamber are separate. As this scrap support or supply equipment is located between the melting chamber and the preheating chamber in the off gas stream, limitation to the off gas temperature exists. The limitation to the off gas temperature directly affects the preheat efficiency and power consumption.

(3) Semi-air tight furnace configuration to avoid scrap oxidation

Semi air tightness avoids over oxidation of the scrap during the preheating. The direct connection of the preheat shaft and the melting chamber and minimized opening of the melting chamber realize the air tightness. In other processes, the melting chamber and the preheating chamber are separate, the melting chamber tilts by itself. This construction requires gap between the melting chamber and the preheating chamber, resulting in excess air infiltration into the preheating chamber. The Oxidation Degree of off gas can easily reach 1.0 with higher oxygen content and not only scrap over oxidation but also scrap melt down adhesion have been reported for other preheating processes.

(4) Improvement of the productivity

In case of a green field project, as the large reduction of the power consumption and stable electric power input level, transformer capacity of ECOARC^{TM} can be small, which is at around 50 – 60 % compared to a conventional furnace with the same productivity. On the other hand, in case of reuse transformer in a re-vamping project, productivity increases by around 50%.

(5) Merit of semi-continuous scrap charge

To maintain certain scrap height in the preheating shaft, scrap is semi-continuously supplied, approx. 10 –13 times a heat. Low bulk density scrap, scrap with excess combustible such as automobile soft press can be easily utilized.

Figure.5 is some sample photos of actually used scrap. Light scrap is mainly used because of its price, high preheat efficiency and metallurgical requirements. Turnings, can press, large scrap are also used. Practically, there is no limitation of scrap in commercial operation.

Figure.5 Raw Material

(6) Merits of flat bath operation

The melting process of the ECOARC^{TM} is continuous flat bath operation.

a) Decrease of Nitrogen pick up

Submerged arc can be easily achieved with sufficient slag in the melting chamber. As the arc always strikes in the slag, the invasion of the air into the molten steel by the arc is decreased. In other words, the invasion of the nitrogen to the molten steel is decreased. There is an operation report that nitrogen content in molten steel decreased by 10 ppm in comparison with a conventional furnace.

b) Decrease of electrode consumption

With the continuous flat bath operation, in ECOARC^{TM}, there is no scrap bore-in period like a conventional furnace. The occasion of electrode breakage by scrap cave-in is decreased, and the arc is stable as arcing takes place between molten steel and electrodes. So decrease of electrode consumption can be expected.

The electrode consumption in the four commercial ECOARC^{TM} is around 0.75 – 1.1 kg/t (all AC furnaces). It is a very good result.

c) Improvement of tapping yield

In ECOARC^{TM}, oxygen is always blown into molten steel by flat bath operation. In other words, there is not so-called scrap cutting work by oxygen lance. From this, generation of excess FeO is avoided in ECOARC^{TM} compared to the conventional EAF. As a result, the tapping yield is improved.

There is an operation result that tapping yield improved around 1.5 – 2.0 % in ECOARC^{TM}.

Environmental Measure

(7) Dioxins, smoke, odor

In the conventional furnace, a burner is installed in the combustion chamber to thermally decompose pollutants. But as regulation is strengthened, it leads to large cost increase.

In ECOARC^{TM}, CO gas from the melting chamber is mixed and burned at a temperature more than 800 degree Celsius in the combustion chamber, then the causative agent of white smoke, odor and dioxins are decomposed. Only a very little fuel of the burners to ignite the CO gas is used. By semi-air tightness, infiltration air to the melting chamber and the shaft is controlled. Then, off gas volume of ECOARC^{TM} is much less than a conventional furnace and it is about 60% compared to a conventional furnace with the same productivity. Therefore off gas becomes high temperature only by burning the CO gas in the off gas.

The problems of pollutant such as white smoke/odor in conventional preheat systems have been solved in ECOARC^{TM} by these processes. The four commercial ECOARC^{TM} have cleared the regulation value of Dioxins in each country.

Pursuit of the preheat efficiency and restraint of the pollutants were contradicting problems. However, the innovative ECOARC^{TM} technology can now provide a solution for the both contradicting issues.

(8) Low dust generation

In ECOARC^{TM}, as there is little quantity of off gas thanks to semi-air tight structure, the velocity of off gas in the shaft is slower than a conventional furnace. In addition, as there is dust adsorption removal effect of the scrap layer in the shaft, reduction in the quantity of dust generation is expected.

As for the quantity of dust generation, an operation result equal or less than around 30 – 40 % is reported for a ECOARC^{TM} after conversion from a conventional furnace. Then, dust processing cost decreases, resulting in production cost reduction.

(9) Improvement of work environment

The noise is largely reduced by the operation of ECOARC^{TM}, because of flat bath operation with sufficient foamy slag and no

scrap charging from top of the furnace.

Figure.6 and Figure.7 are the result noise level measurement at the time of operation of a conventional furnace and an ECOARC^{TM} with the same productivity. In the conventional furnace, the noise level more than approximately 100 dB was recorded in the melting period. On the other hand, the noise level in ECOARC^{TM} was always less than 100 dB and around 90 -95 dB in average.

In addition, as there is no scrap charging with roof open like a conventional furnace, there is no large fly dust by scrap charging with roof open. Then, the environment inside the meltshop building is kept clean in comparison with the conventional furnace.

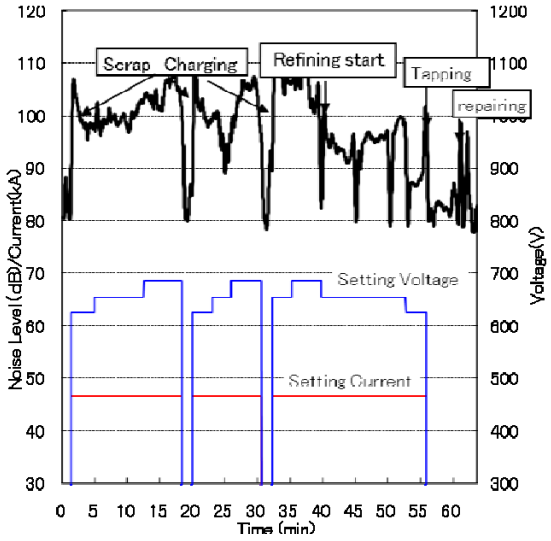

Figure. 6 Noise level measurement in conventional EAF

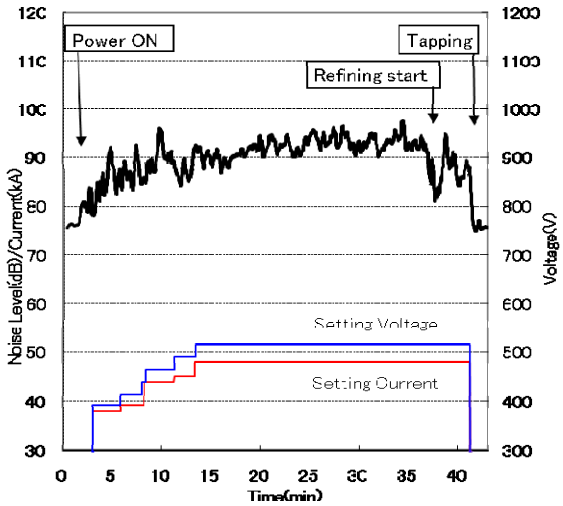

Figure. 7 Noise level measurement in ECOARC^{TM}

(10) Power supply quality

As ECOARC™ is always flat bath operation, there is no big fluctuation of power input as seen in a conventional scrap melting furnace. Then, it is possible to keep high power factor, low flicker and low higher harmonics throughout a heat. Therefore, the electric facilities necessary to meet power quality regulation(SVC, higher harmonics filter, etc.) can be drastically reduced or it may not even unnecessary depending on required regulation.

Figure.8 shows flicker measurement value in ECOARC™. In addition, Figure.9 and Figure.10 are comparison of higher harmonics distortion for one heat between a conventional furnace and an ECOARC™. From these measurements, it is easy to understand that the ECOARC™ has a great advantage in impact to the power quality requirements mentioned above.

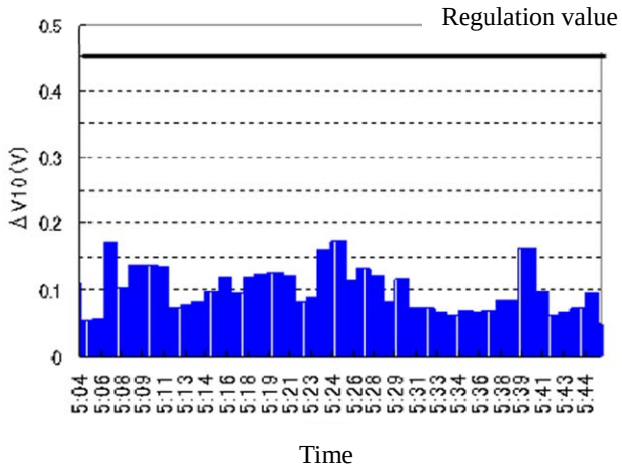

Figure. 8 Flicker measurement in ECOARC™

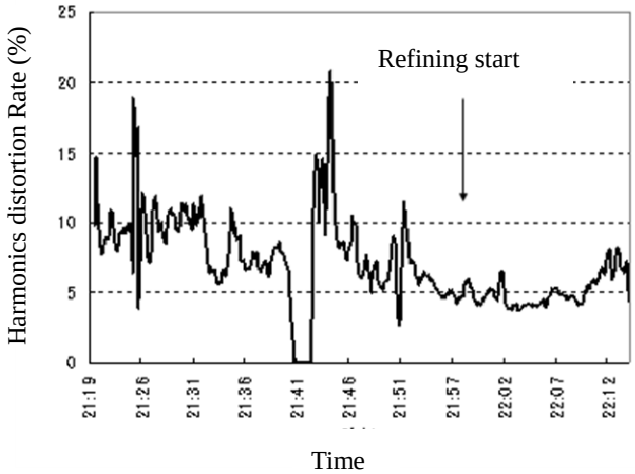

Figure. 9 Harmonics Distortion rate measurement in Conventional EAF

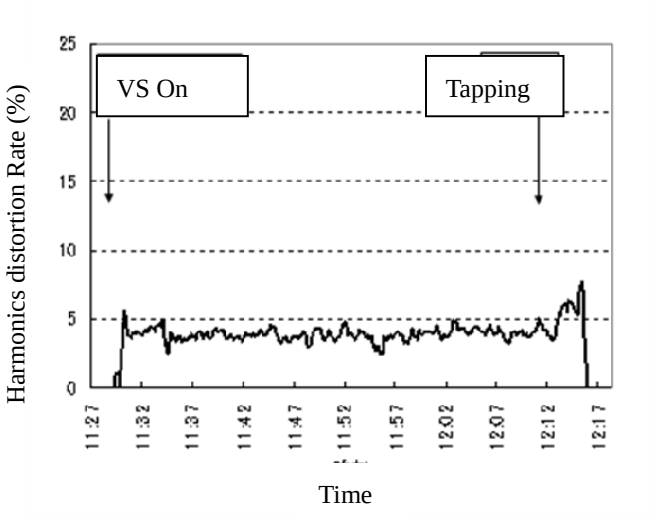

Figure. 10 Harmonics Distortion rate measurement in ECOARC^{TM}

(11) Quantity of CO_2 emission

ECOARC^{TM} is expected to achieve power consumption reduction by about 100 – 150 kWh/t from a conventional furnace with the same productivity. As the quantity of CO_2 emission per electric power in Japan is 0.4 kg-CO_2/kWh, ECOARC^{TM} can reduce 40 kg CO_2 per 1(one) ton steel production when the reduction effect of power consumption by ECOARC^{TM} is 100 kWh/t.

(12) Easy operation

In ECOARC^{TM}, most operation is automated including scrap blend instruction, scrap handling, sub material blend instruction and handling, etc. The operator in pulpit operate the ECOARC^{TM} through the HMI and a small desk top control station. Figure.11 shows the picture of operation room for example.

Figure.11 Operation Room

In addition, the operator of the scrap bucket charging crane becomes needless because there is not work for scrap charging with scrap bucket, which is essential in a conventional furnace. Furthermore, the work in front of the furnace can be done only by one operator because the work is limited to de-slagging, observation of slag, temperature measurement, and sampling of molten steel(an automatic measuring machine is also provided).

Therefore, two(2) operators (one in pulpit, one in front of furnace) are enough to run the ECOARC^{TM} .

4. Commercial Application

Table 1 shows the main specification of the four operating ECOARC^{TM}.

Table.1 Main Specification of ECOARC^{TM}

NO	1	2	3	4
Start up year	2001	2005	2008	2010
Country	Japan	Japan	Japan	Korea
Heat size	70 ton	140 ton	130 ton	120 ton
Furnace Type	AC	AC	AC	AC
Trans Capacity	41 MVA	88 MVA	75 MVA	80 MVA
Electrode	20 in	24 in	24 in	22 in
Product	D-Bar	H-beam, FB, Angle	Rod/Wire For Automobile	D-Bar

5. Conclusion

JP Steel Plantech has developed a new concept arc furnace "ECOARC^{TM}" having innovative features of low power consumption, which cannot be definitely impossible to achieve by a conventional arc furnace, and at the same time, coping with the expected environmental regulations. The concept of the "ECOARC^{TM}" is based on totally new ideas, which are,

a. Directly connected monolithic structure of preheat shaft and melting chamber

b. Shaft fully filled with scrap throughout a heat and

c. Scrap and molten steel co-existing in the melting chamber

d. Continuous and even preheat of scrap throughout a heat

Through the stable operation of the first commercial plant, JP Steel Plantech has confirmed that 200 kWh/t with 40 m^3_N /t oxygen is an achievable value.

In addition, 2nd to 4th ECOARC™ are operating smoothly and they keep updating many operation records.

In an EAF, production cost reduction and the recent environmental measures are contradicting issues, which can however be realized by the innovative ECOARC™ technology.

We believe the ECOARC™ will contribute to more eco-friendly iron and steel industry and society.

Reference

[1] Cesare Giavani et al.「Comparison in Maintenance Practices Between a Consteel EAF and a Conventional EAF」AISTech 2009 Proceedings, Volume-1