

Optimization of PyreJet™ wall mounted multi-function injection tool for stainless steel and flat bath steelmaking operations.

Introduction

For the last 20 years, American Combustion (ACI) has been a technology leader in providing combustion solutions by constantly introducing new and innovative solutions for the steel and non-ferrous metal industry.

ACI was the first company to use a flame shroud around a supersonic oxygen jet on its **PyreOx™** and **PyreJet™** burner technology for EAF steelmaking.

Firstly developed for carbon steel operations, **PyreJet™** offers four main steelmaking function within one single tool :

- melting with oxy-fuel burners,
- refining with supersonic oxygen lance,
- slag foaming with parallel carbon injection,
- post combustion with an optional dedicated co-axial and low speed oxygen injection.

The flame shrouded supersonic oxygen injection which has been successfully implemented by ACI on 40 EAF worldwide, brings two main benefits ;

- savings in electrical , refractories and electrode consumptions
- productivity enhancement thanks to decrease of TTT and increase of metallic yield.

For a long period of time, metallurgical, mechanical and economical issues have prevented the use of such technology in specific domain as stainless or flat bath practices.

 AIR LIQUIDE



PyreJet™ in Stainless steel EAF operations

In October 2001, a **PyreJet™** wall-mounted combined burner injector was installed on the EAF of Arcelor Industeel Belgium (AIB) in Charleroi – Belgium for a test period. In August 2002 a complete 4 **PyreJet™** system was commissioned.

AIB, a Belgian steelmaker, part of Arcelor group operates a 188 T AC electric arc furnace (150 tapped T in stainless) and produces carbon, stainless and alloyed flat products. Downstream the EAF, AIB operates a VOD which requires a decarburization in the furnace (delta of 0.6 %).

The use of multi-function supersonic wall mounted tool on stainless steel practices is a world premiere.

The main challenge for the **PyreJet™** technology in stainless steel operations was :

- the ability of the supersonic jet to cross the chromite containing crusty slag that characterizes stainless steel,
- the stability of chromite rate in order to maintain equivalent chromium losses.

After two years of operations, the overall conclusion is positive :

- Supersonic O2 jet is able to go through crusty slag without projection and with no melt over-oxidation. This decarburization, done arc on for stirring effect and at high temperature enables a significant decrease of power off time.
- Slag door remained mostly shut, avoiding entrance of fresh air permits to maintain a stable chromite rate. Reduction of door lance's use contributes to decrease operating hours during stainless steel practices, moderately useful for AIB, since VOD is bottleneck.
- A drawback is an increase of electrode consumption mainly due to tilting conditions of the furnace which did not allowed to install PyreJet in optimistic position between electrodes.

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This first reference has proven the efficiency of **PyreJet™**, Air Liquide's wall mounted multi-function supersonic tool in stainless steel operations, specially when operated with VOD.

PyreJet™ in flat bath operations

In conventional bucket charged furnaces, scrap is batch charged. Usually 2 or 3 buckets of scrap are required to make a heat of steel. The number of buckets required to make a heat of steel depend on the following factors:

- Scrap density
- Bucket Size
- Furnace Shell Height

Scrap is typically charged in enough quantity to fill the entire shell to the roof. During melting, oxy-fuel burners placed in the cold spots of the furnace enable uniform melting of the scrap.

Most modern furnaces use multi-functional tools that can be used as burners when there is a large proportion of unmelted scrap in the furnace and that can inject supersonic oxygen when the scrap is melted into the flat bath.

Most multifunctional burners on the market always rely on the flame envelope to be able to produce a high enough quality supersonic jet of oxygen for refining. However, for furnaces that do not operate with significant proportions of unmelted scrap, the burner function is not necessary because there is no scrap to melt in front of the burner.

Therefore, significant quantities of fuel are wasted in order to preserve the integrity of the supersonic jet. Such furnaces include:

Furnaces where scrap is preheated using fumes from the furnace. Hot scrap is continuously charged into the hot bath.

DRI furnaces operating with more than 30% DRI and continuously charging the DRI into a flat bath.

Furnaces using large proportions of molten hot metal from the blast furnace. Very little solid scrap is present in such a furnace.

These operations have very little unmelted scrap in the furnace so they do not require oxy-fuel burners for melting.

PyreJet™

Air Liquide has developed the optimized **ALARC-Jet™** nozzle for such EAF operations where the majority of the power on time is spent under flat bath conditions and where the furnace temperature atmosphere is much higher and more stable when compared to a scrap furnace. More than 20 furnaces worldwide have been equipped with the new **ALARC-Jet™** nozzle.

A **PyreJet™** equipped with an **ALARC-Jet™** nozzle does not require any flame shrouding because it produces a high quality supersonic stream of oxygen that maintains its supersonic velocity over large distances (see Figure 1).

This makes it a cost-effective and easy-to-use tool for flat bath EAF operations when the burner function is not necessary.

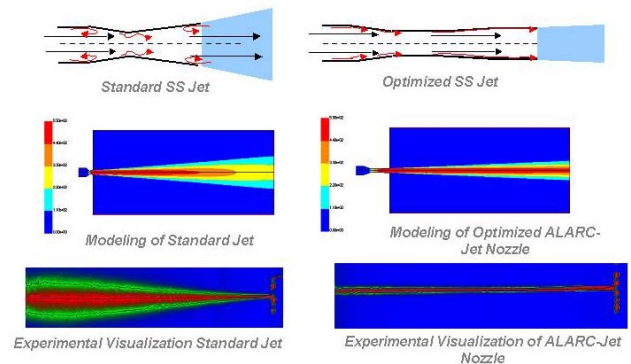


Figure 1. Comparison between a conventional supersonic nozzle and the ALARC-Jet™ nozzle.

The typical **PyreJet™** system consists of multiple injectors - each equipped with a carbon injection. Figure 2 shows typical layout

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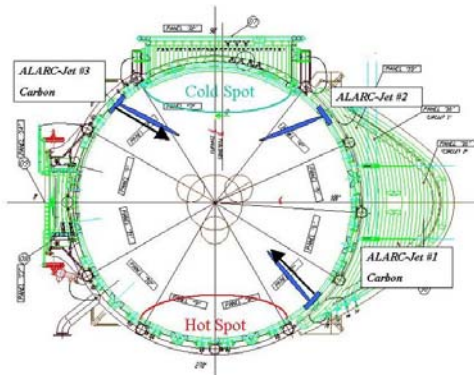
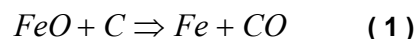


Figure 2. Typical PyreJet layout

In the CONSTEEL type of furnace, the injectors are concentrated close to the location where the relatively cold scrap falls into the bath. The energy generated from refining and decarburization improves the rate of melting of the scrap below the conveyer.

The *PyreJet*™ injectors are arranged around the circumference of the furnace to provide efficient decarburization at multiple locations. Not to mention the safety hazard linked to conventional operations using a slag door lance, this tends to over-oxidize the slag in front of the slag door because bath mixing in the electric furnace is typically poor. For a furnace that decarburizes at multiple locations, bath decarburization can occur to the same extent as a conventional operation without locally over-oxidizing the slag. In addition to this advantage, carbon injection is located close to oxygen injection point to provide a foamy slag by utilizing the following reaction:



The foamy slag Reaction 1 reduces the FeO with carbon to make CO that foams the slag. Both mechanisms improve the yield of metal. Additionally, the foamy slag buries the arc, which increases the arc energy input, shields the refractory and furnace shell from the intense arc radiation. This increases the rate of electrical energy input and reduces the overall energy consumption.

Hot Metal in the EAF

The distribution of decarburization oxygen around the circumference of the furnace is

particularly important in furnaces that charge large proportions of blast furnace hot metal. When refining a melt with a high concentration of carbon (hot metal consists of more than 4 percent carbon) in such a poorly mixing vessel like the EAF, large carbon concentration gradients will result if all refining is performed using only the conventional door lance.

ACI proved over time that when charging large proportions of hot metal (> 50%), it is necessary to install enough supersonic injectors around the furnace, and inject at a high enough rate so that production rate is not limited by the rate of oxygen injection. At the same time, it is necessary to arrange the injectors around the furnace so as to minimize carbon and silicon concentration gradients.

In China, the scrap shortage has forced steelmakers to rely on molten hot metal to make steel in the EAF. One steelmaker recently equipped two of their three standard ACI *PyreJets*™ with optimized *Alarc-Jets*™ nozzles so as to be able to continuously increase the proportion of hot metal while saving money on liquid propane (that is not necessary in flat bath operations). Figure 3 shows charging of blast furnace iron in the EAF.

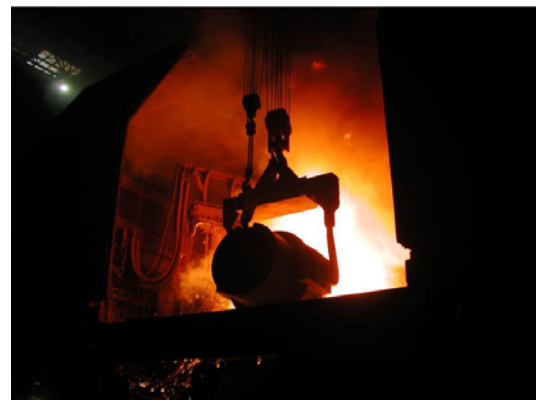


Figure 3. Hot Metal Charging in the EAF.

After upgrading the *PyreJets*™ with *ALARC-Jet*™ nozzles that steelmaker was still able to achieve decarburization rates of approximately 0.15% carbon per minute. This rate of decarburization is double that of conventional multi-functional burners.

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	PyreJet Average	ALARC-Jet Average	PyreJet Heats with 30 - 40% HM	Alarc-Jet Heats 30 - 40% HM
1st Charge (tonnes)	61.80	54.04	55.15	51.95
Hot Metal (tonnes)	28.37	41.73	42.55	40.72
2nd Charge (tonnes)	31.00	24.16	24.00	26.65
Percent Hot Metal	23.3%	34.8%	35.0%	34.2%
Total KWh	26085	21330	21726	21270
Estimated (KWh/tonne)	261	213	217	213
O2 Used by Door Lance (Nm3)	2448	2728	2448	2226
O2 Used By Injectors (Nm3)	1974	2385	1974	1852
POT (min)	33	14	25	26
TTT (min)	57	57	48	51

Table 1. Comparison between the ALARC-Jet nozzle and the PyreJet standard nozzle with heats using large proportions of hot metal.

Table 1 shows that the performance of the **ALARC-Jet™** nozzle (without the flame shroud) was just as good as the **PyreJet™** standard nozzle (with a flame shroud) for heats made with 30 – 40 % molten blast furnace iron.

This article summarizes and illustrates the benefits that can be expected from supersonically injecting oxygen in the EAF, both for stainless steel and flat bath carbon steel.

The choice of the tool to be used for the oxygen injection and its implementation on the furnace should be governed by the cost-effectiveness of the system.

PyreJet™ as a multi function tool has proved particularly adapted to furnaces using a significant proportion of unmelted scrap.

When equipped with an optimized **ALARC-Jet™** nozzle **PyreJet™** can cost-effectively provide a high oxygen efficiency for furnaces using preheated scrap, DRI or molten hot metal from the blast furnace, even without the flame shroud.