

PYREJET™ – A MULTI- FUNCTION SYSTEM FOR EAF STEELMAKING : INDUSTRIAL RESULTS AT LME (FRANCE)

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ABSTRACT

The French steelmaker Laminés Marchands Européens (LME) operates a 100 T DC EAF at Trith Saint Léger (France), with a long-lived tradition of developing constantly an efficient energy optimisation. In continuation with this strategy, the Air Liquide PYREJET™ technology for EAF steelmaking, already in operation in more than 18 EAF plants worldwide, has been successfully implemented in 2001 on the EAF at LME, to go further in increasing the productivity and optimizing the energy costs. The industrial results indicate improvements and savings such as 22 kWh/tons electrical savings, 3 min decrease in tap to tap time, increased oxygen efficiency and increased panel life. The present technology implemented at LME utilizes one burner/injector as a complement to the traditional “through-the-door” oxygen injection technology. In a second step, the PYREJET™ system with 2 or 3 tools is planned to take the major part of the oxygen injection in the EAF and will improve the existing and excellent results with one single tool.

KEYWORDS

EAF, PYREJET™, ALARC-PC™, Carbon, Oxygen, Slag foaming, Melt refining

1. INTRODUCTION

Laminés Marchands Européens (LME) is a French steelmaker, part of the Italian Group AFV / BELTRAME, with a share ownership split between AFV / BELTRAME (Italy) for 66 % and ARBED (Luxembourg) for 34 %. LME produces and commercialises 950 000 tons of merchant steel bars, with its headquarters based in Trith St Léger (France).

American Combustion (ACI), a division of AIR LIQUIDE, has developed PYREJET™, a new proprietary multi-functional tool for the Electric Arc Furnace (EAF) which realizes the incorporation of the followings functions in one single, process controlled wall mounted tool :

- efficient oxy-fuel burner,
- advanced supersonic oxygen lance,
- carbon injection

The PYREJET™ system is in operation in more than 18 installations world-wide and can be tailored for each individual operating conditions to optimize energy cost and maximize the EAF output (see [1]).

LME has a long-lived tradition of being on the leading edge of advanced technologies. For instance, LME was the first world-wide reference to operate a DC EAF industrially [2]. LME also installed ALARC-PC™ for optimized Post-Combustion [3,4,5]. In continuation with that tradition, LME has decided in 2001 to install the PYREJET™ system on its 100 T DC EAF situated in Trith St-Léger, France, with the following targeted objectives:

- Increase productivity
- Reduction in electrical power consumption
- Reduction in power-on-time
- Increased oxygen efficiency
- Reduction of refractory wear

2. LME : INDUSTRIAL CONTEXT DESCRIPTION

2.1. Company presentation

Laminés Marchands Européens has been privatised since 1994, when the Italian Group BELTRAME / AFV took over the major shareholding of the company and ARBED (Luxembourg) became the minority shareholder.

LME has two production facilities located in Trith St-Léger, near Valenciennes in the North part of France :

- an electric steel plant producing 680 000 tons of billets per year
- a rolling mill producing 360 000 tons of merchant steel bars per year.

And two rolling mills subsidiaries:

- a rolling mill situated in Belgium at Le Ruau-Marchienne, near Charleroi, with a yearly production of 260 000 tons of merchant steel bars.
- a TLM rolling mill, located at Schiffange in Luxembourg producing 250 000 tons of merchant steel bars per year.

The rolling mills of Trith St-Léger and of Le Ruau are supplied with billets from the Trith St-Léger steel plant, while the TLM rolling mill is supplied by the steel plant of ARES, which is located in the near surrounding.

The electric steel plant of LME, built in 1985, was the first world-wide reference to operate industrially a DC electric arc furnace. The melt shop comprises the followings production equipment:

- a 100 ton DC EAF from CLECIM powered by a 72 MVA transformer (detailed characteristics presented in table n° 1).

- a ladle furnace from Badische Stahl Engineering (BSE) equipped with 17 MVA transformer
- a continuous casting machine CONCAST CLECIM with 5 strands and a bending radius of 6 m. It produces billets of 125 x 125 mm and of 140 x 140 mm.

After step-wise improvements, the production has been increased up to 660.000 tons of billets in the year 2000.

Inside diameter of panels	5.5 m
Height of the shell	3.2 m
Number of bottom anode electrodes	3
Diameter of the graphite electrode	1 x 710 mm
Weight of the scrap (2 buckets)	100 tonnes
Tapped weight	92 tonnes
Maximum power input	50 MW
Lances manipulator from BSE	
* 2 oxygen lances	2 x 1500 Nm ³ /h
* 1 carbon lance	1 x 30 kg/min
Post-Combustion injectors ALARC-PC™	5 x (80 to 500 Nm ³ /h)

Table 1: Characteristics of DC EAF at LME

2.2. Energy optimization at LME – historical evolution

Within the last 15 years, the industrial strategy implemented by LME has been constantly focused on energy savings. This energy optimisation is a key parameter for a secure development of the company, which continually strives to be at the forefront of the persistently aggressive competition ([6,7,8]).

The efforts realized during the last years for the optimisation of the EAF energy consumption have not only allowed to successfully face the industrial challenge regarding the rational use of energy, but have also ensured permanent improvements of the productivity and cost reductions.

Fig. 1 indicates the evolution of the specific electrical consumption of the EAF per ton of good billets. A simple observation of the registered improvements regarding this consumption shows perfectly the successful results obtained by the constant actions led by LME in this domain.

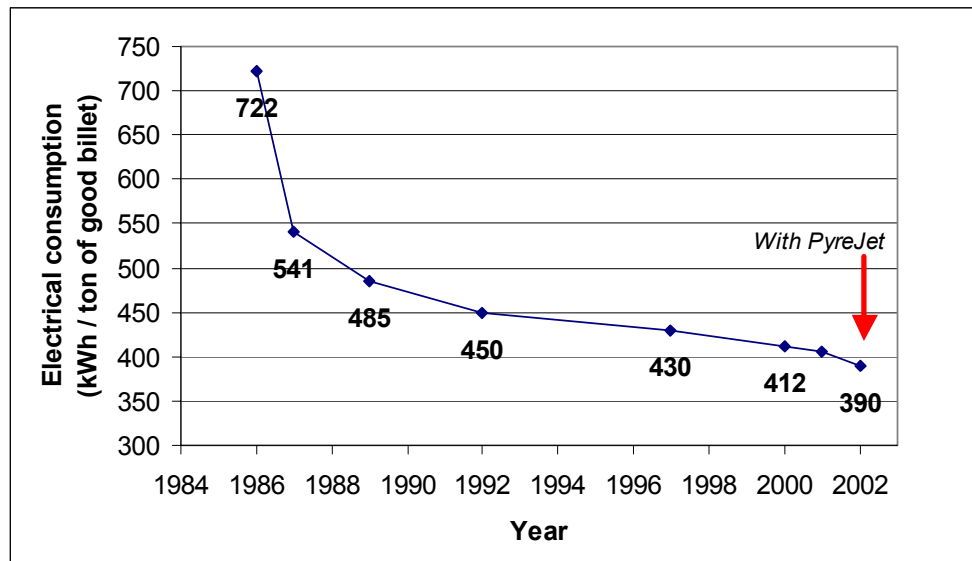


Fig 1: EAF specific electrical consumption at LME

In extension of the door lance manipulators (BSE), which includes 2 oxygen lances and one carbon lance, the EAF was equipped in 1999 with an ALARC PC™ post combustion system (patented by Air Liquide) consisting of 6 wall mounted oxygen injectors.

In 2001, LME decided to install one PYREJET™ tool at the back of the EAF, for taking advantage of the combined injections of supersonic oxygen, natural gas and carbon in order to go further in reducing the electrical consumption and increasing the productivity (680,000 tons per year).

3. PYREJET™ SYSTEM DESIGN AND OPERATING STRATEGY

Pioneered by American Combustion (ACI) in the mid-80's (first ACI patent has been granted in 1986), the PYREJET™ system comprises multiple wall mounted injectors, which are installed in several locations in the EAF to assist scrap melting and melt refining.

The system can combine several PYREJET™ multi-functional injectors and oxy-fuel PyrOx burners (PyrOx and PYREJET™, US Patent N° 4,622,007; 5,599,375; 5,788,921; 5,858,302).

3.1. PYREJET™ Design

The PYREJET™ design gives not only the ability to melt and cut the scrap, but comprises several additional features. This enables this multi-functional tool to be used for the efficient combined injection of carbon fines and supersonic oxygen, which enhance slag foaming and melt refining. The water-cooled copper burner tiles have a deep combustion chamber to control flame formation and flame shape. The combustion chamber also protects the gas and oxygen discharge holes from plugging with splashed slag and steel. The inner part of the burner can be quickly and easily disconnected from the combustor allowing 'on-the-fly' burner change out, when necessary. The PYREJET™ is also equipped with a replaceable carbon injection pipe located near the burner centerline. This allows carbon to be entrained and driven into the slag by a highly aspirating supersonic oxygen stream.

The PYREJET™ tool is typically integrated in a compact water-cooled copper sub-panel, which is part of the total system. A typical installation is shown in Fig. 2.

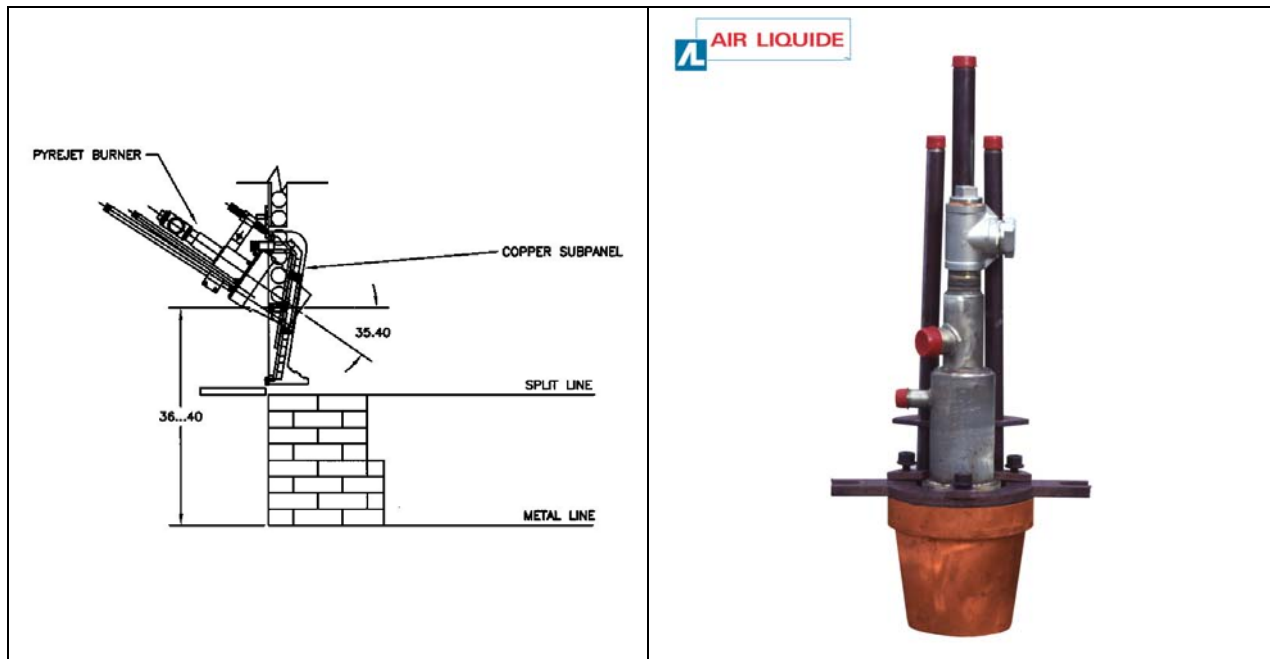


Fig 2: Typical PYREJET™ installation (left) and assembly (right)

3.2. Flame Enhanced Oxygen Lancing

The length of a supersonic oxygen jet is greatly influenced by the condition of the gaseous atmosphere surrounding the jet. The main reason for a conventional supersonic lance's jet normal disintegration is the interaction with surrounding atmospheric gases. The high velocity supersonic jet entrains the surrounding atmosphere. This increases the mass of the jet stream and reduces its velocity.

Flame shrouding of a supersonic oxygen jet stream was first described and patented by ACI in 1986 (US Patent No 4,622,007). The use of an oxy-fuel flame provides for high temperature combustion gases accompanying the oxygen jet stream. High temperature combustion gases have very low density as shown in Fig. 3. This reduces the mass of inspired gases and keeps the oxygen jet stream focused along a greater distance.

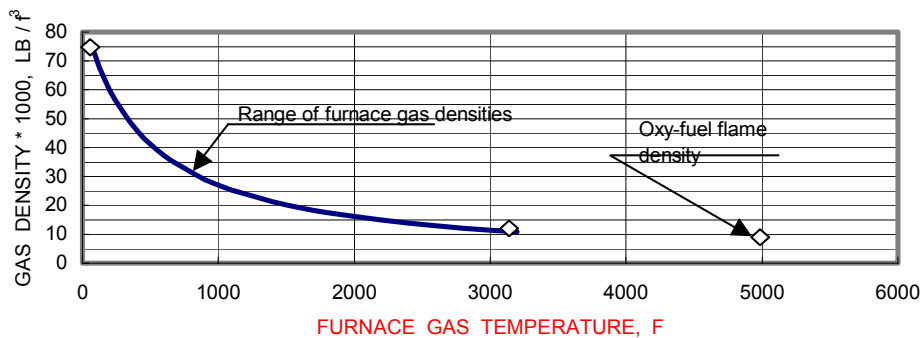


Fig 3: Density of oxy-fuel flame vs. Temperature

3.3. PYREJET™: operating mode

Recognizing that EAFs have different operating conditions, the PYREJET™ system has been designed to optimize EAF performances by utilizing multi-points injection of auxiliary heat, metallurgical oxygen, carbon fines and post combustion oxygen. The main differences are due to a variation in furnace design, electrical power, scrap mix and established melt shop operating practices. Optimization of the PYREJET system in each case is carried out during the burner system design phase as well as installation and commissioning.

A final melt carbon content as low as 0.02% can be accomplished by using PYREJET™ technology. The PYREJET™ system control program is fully automated to ensure the consistency of the EAF operation.

System Optimization includes the following:

- Selection of appropriate number of burners and their positions
- Estimated firing schedule
- Oxygen lancing schedule
- Layout of carbon fines injection points and carbon injection schedule

The detailed generic operating mode and metallurgical principle of PYREJET™ is available in [1] or [9].

From burner mode to lancing mode

At the beginning of each charge, the PYREJET™ operates as regular oxy-fuel burners heating the scrap located in the cold spots. After the scrap is preheated and partially melted in, the fuel and oxygen flows are reduced and the central oxygen flow is increased to initiate soft lancing in order to cut scrap in the more remote areas and get access to the melt. The self-protecting design of the injectors allows for a reliable, low maintenance operation. Aggressive oxygen lancing begins when both stages of carbon removal are kinetically feasible to prevent slag over-oxidation [9].

Simultaneous oxygen lancing and carbon injection

To avoid local slag over-oxidation, oxygen lancing is accompanied by simultaneous carbon co-injection, especially if the final melt carbon content is below 0.1%. Carbon injection may be initiated simultaneously with oxygen lancing to balance the slag temperature and chemistry in the jet impact area, enhancing foamy slag formation. If the scrap mix contains a substantial amount of excess carbon, the carbon fines injection can be delayed to allow oxygen to perform an initial rapid reduction of the melt carbon. The final amount of oxygen and carbon introduced by the PYREJET™ multi-functional tools is calculated on the basis of the scrap mix and the desired melt carbon content.

Oxygen utilization and the consistency of foamy slag practice can both be improved via utilization of multiple points of oxygen/carbon co-injection in the EAF. Multi-point co-injection also provides for better nitrogen control, lower refractory erosion and metallic yield increase. Main benefits of the PYREJET™ system are detailed below.

Increase in Power Input

The homogeneous and efficient foamy slag layer created by the PYREJET™ allows increasing the active power input, especially during the refining period. The EAF voltage can

be increased with flat bath without negative effects of arc radiation on the water-cooled panels. Values up to +10 % are reachable, if the transformer capacity permits.

Refractory savings

A thick layer of foamy slag generated by the use of PYREJET™ not only improves electrical efficiency and metallic yield but also protects the refractory from erosion. The thick slag layer may help to capture some of the oxygen that may rebound from the metal interface as well as droplets of metal that are inevitably generated during lancing. The endothermic reaction of injected carbon with slag oxides reduces the temperature and slows the chemical attack of slag before its basicity increases due to the lime dissolution.

Metallic yield

During normal oxygen lancing operation, slag is “flushed” from the furnace beginning very early in the heat cycle. This slag typically is highly oxidized due to the proximity of the oxygen lance. Early flushing of this oxidized slag early in the heat cycle leads to a decrease in metallic yield. Contrary to traditional EAF operations, a PYREJET™ system allows the slag to be maintained in the EAF until late in the heat cycle. Not only does the EAF operator have the ability to maximize electrical power input and energy transfer efficiency, but also allows time for the slag to be reduced by the injected carbon, thereby increasing the metallic yield.

4. INDUSTRIAL RESULTS AT LME (TRITH ST LEGER)

4.1. PYREJET™ Implementation

The PYREJET™ system was installed on the EAF in March 2001. One PYREJET™ tool of 2000 Nm³/hr oxygen and 30 kg/min carbon capacity has been implemented between the exhaust gap and the EBT area (Fig. 4). The tool is oriented with a 15° angle in order to avoid facing the electrode (Fig. 5).

It is noteworthy that this location was the hot spot of the furnace, with the highest panel temperature, making the installation of the tool even more challenging.



Fig 4 : PYREJET implementation on the EAF



Fig 5 : PYREJET™ and its associated copper panel

The injection of carbon through the PYREJET™ is controlled by the same system as the door manipulator, with one additional distribution line.

4.2. Industrial results

The scrap mix at LME consists of shredded, obsolete, heavy obsolete scraps, busheling, turnings and pig iron (3%). The tap carbon is typically 0,06 %.

Table 3 represents comparison of the main operating data before and after the installation of the PYREJET system after one year of operation.

<i>All values in tons of good billets</i>	Reference	with PyreJet™	Delta
Electrical Consumption, kWh/tons	412	390	- 22 kWh/t (-5,3 %)
Natural Gas Consumption, Nm ³ /tons	0	1.5	+ 1.5
Oxygen Consumption, Nm ³ /tons	35	39	+ 4 Nm ³ /t (+11,5 %)
Total Carbon (charge, lance, PyreJet), kg/tons	13	16	+ 3 kg/T (+23%)
Tap to tap, min.	60	57	- 3 min (- 5 %)
Metallic yield, %	92	92	=

Table 3. Addition of one PYREJET at LME - Operating Results
Average data measured on more than 300 heats

The PYREJET™ tool is continuously operating, together with the classical door manipulator which has been kept in operation with oxygen and carbon injection.

Thanks to the supersonic oxygen lancing combined with the carbon injection function, located in an optimal position at the back of the EAF, the PYREJET™ operation has accelerated the steel refining and has created a much more homogeneous and efficient foaming slag. This has allowed, in addition to all process improvements shown in Table 3, to reduce the panel temperature in the EBT area and to increase the panel life.

Also, the metallic yield has remained constant, indicating no negative influence of the PYREJET™ on the iron oxides creation, thanks to the optimal combination O₂/carbon, although using more oxygen and having increase the productivity.

The PYREJET™ system is fully compatible with the existing ALARC-PC installation. Both systems are complementary and are perfectly operating together, complementing each other. Indeed, thanks to a better foaming slag in the back of the EAF and the decreased panel temperatures, it has been possible to restart the sixth ALARC PC injector, which has given a better oxygen injection distribution and more flexibility.

After more than 7000 heats, the initial PYREJET™ tool is still in operation, confirming excellent robustness resulting in low maintenance costs.

For 2002, the installation of a complete PYREJET™ system, which will consist in 2 to 3 tools, is currently pending.

5. CONCLUSION

Air Liquide PYREJET™ technology for EAF steel making, already in operation in more than 18 EAF plants worldwide, has been successfully implemented on the 100 T DC EAF at LME in Trith St Léger .

The results of the first step of the project with one tool in operation, indicate improvements in the following areas:

- 22 kWh/tons electrical savings, with only 4 Nm³/ton supplemental oxygen
- 3 min decrease in tap to tap time
- Enhanced foaming slag formation
- Increased oxygen efficiency
- Increased panels life time

The PYREJET™ technology is actually operated at LME in parallel with the traditional “through-the-door” oxygen injection technology and has been proven totally compatible with ALARC-PC technology.

In a second step, the PYREJET™ system with 2 or 3 tools is planed to take the major part of the oxygen injection in the EAF and will improve the already existing and excellent results with one single tool.

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