

# ACI PYREJET™ TECHNOLOGY: A KEY STEP IN JYXC's STRATEGY TOWARDS WORLD CLASS SPECIALTY STEEL PRODUCTION

Qian GANG, Li WENSHUANG, Xu XIAOHONG  
Jiangyin Xing Cheng Steel Works  
297, Bin Jiang East Road, Jiangyin City, Jiangsu Province, P.R. China

Olivier DELABROY, A. POPENOV  
ACI, division of Air Liquide America L.P.  
200, Chastain Center Bvd, Suite 295, Kennesaw GA 30144, USA  
corresponding author : olivier.delabroy@airliquide.com

Charles CHEN  
UET International  
9 Riva Ridge Lane, Bear DE 19701, USA

## ABSTRACT

Jiangyin Xing Cheng Steel Works, P.R. China, has been operating a 100 ton DC Furnace for 5 years to produce a wide range of products, including specialty ball-bearing steel. This article presents the continuous improvement of EAF practices, which now enable electrical energy consumption as low as 310 kWh/tonne for 100% scrap charging. The implementation of ACI's PyreJet technology is one of the key steps of JYXS ongoing optimization efforts. In October 2002, JXCS started a blast furnace to supplement a portion of the scrap with liquid hot metal. Results presented in this paper include 100% scrap charging as well as 20% hot metal charging. ACI and JYXS continue their cooperation to implement innovative oxygen injection technologies that will allow up to 60% hot metal charging.

**KEYWORDS** EAF, PYREJET, Carbon, Oxygen, Slag foaming, liquid hot metal

## 1. INTRODUCTION

Jiangyin Xingcheng Steel Works Co., Ltd is jointly set up by Jiangyin Steel Plant and HongKong CITIC Pacific Co., LTD and has been ranked in China's 50 biggest enterprises since 1995. Its annual output is 1.1million tons of quality and special steel and 1 million tons of special steel products. The company has been awarded as one of the top ten enterprises of service quality by China Quality Management Association.



Fig 1 : JiangYin XingCheng plant, Jiangsu Province, P.R. China

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 following functions in a single process device:

- efficient oxy-fuel burner,
- advanced supersonic oxygen lance,
- carbon injection
- Useful post-combustion of CO

The PYREJET™ system is in operation in more than 20 furnaces worldwide and can be tailored for a variety of operating conditions to optimize energy cost and maximize the EAF output. PyreJet™ is implemented on both DC and AC furnaces that produce carbon steel, special steel and stainless steel and utilize some alternate iron sources such as DRI, HBI and hot metal. [1,2,3].

JiangYin XingCheng main objective is to increase the plant production capacity. To reach this goal, two main developments have been performed in 2002:

- **Maximize EAF chemical energy input and efficiency** by implementing PyreJet™ technology,
- Commission new blast furnace and **charge hot metal in the EAF**, up to 60% of the charge (see Fig. 2)



Fig 2: Hot Metal Charging in JYXS Electric Arc Furnace

## 2. JYXS : INDUSTRIAL CONTEXT DESCRIPTION

### 2.1. Company overview

Jiangyin Xingcheng Steel Works Co has three plants located around the city of JiangYin (Jiangsu province, P.R. China). This paper focuses on the special steel plant located in the urban district of Jiangyin, a newly developing industrial port city at the golden section of the

Changjiang river (Yangtze) Delta. Located right on the river, the company enjoys its unique natural advantage of geography and transportation. The company covers an area of 1.59 square kilometer with a one kilometer-long bank along the Changjiang River, and it has its total assets of 3,000 million Chinese yuan.

This plant, with an up-to-date advanced special steel production line (short-flow process) and one production line of steelmaking, refining, continuous casting and rolling, has become a large special steel producer of carbon steel, alloy steel, bearing steel, spring steel, gear steel, cold-heading steel, steel for cars and corrosion-resistant steel.

The JiangYin Xincheng Special Steel plant's EAF has been operating since Nov. 1997. The melt shop comprises the followings production equipment:

- a 100 ton DC EAF powered by a 90 MVA transformer (detailed characteristics presented in table 1).
- a Demag ladle furnace equipped with 16 MVA transformer
- a continuous alloy steel Demag casting machine with 5 strands producing 12 m billets of 300 x 300 mm and of 180 x 180 mm.
- 16-stand high-rigid continuous rolling mills

The last major addition to the plant is the blast furnace from China Metallurgical Equipment Central Company. The 380 m<sup>3</sup> blast furnace has been successfully operating since September 2002 and now allows hot metal charging into the EAF (Fig. 2).

|                                    |                             |
|------------------------------------|-----------------------------|
| Manufacturer                       | DEMAG                       |
| Current                            | DC                          |
| Inside Shell Diameter              | 6.5 m                       |
| Tapped weight                      | 100 tonnes                  |
| Transformer                        | 90 MVA                      |
| Maximum power input                | 60 MW                       |
| Diameter of the Graphite Electrode | 1 x 711mm                   |
| Number of bottom electrodes        | 4                           |
| Lances manipulator from Demag      |                             |
| * 2 oxygen lances                  | 2 x 2000 Nm <sup>3</sup> /h |
| * 1 carbon lance                   | 1 x 75 kg/min               |
| Tapping Temperature                | 1630 °C                     |

*Table 1: Characteristics of DC EAF at JYXS*

## 2.2. Energy optimization at JYXC – historical evolution

The evolution of annual steel production and average EAF electrical consumption of the special steel plant is shown in Fig. 3. The industrial strategy implemented by JYXS has been constantly focused on energy savings. This energy optimisation is a key parameter for a secure development of the company [4,5,6].

The efforts realized during the past years have also ensured continuous improvement of the plant productivity, with an increase from 364,000 ton in 1999 to more than 790,000 ton in 2002.

The last improvement is the start-up of the blast furnace allowing molten pig iron charging in the EAF. This paper describes the practices and results with up to 20% hot metal charging. The JYXS charging practice is as follows: after the charge of the first bucket, the power is on for approximately one minute, then the roof is opened to allow the pouring of hot metal (see Fig. 2).

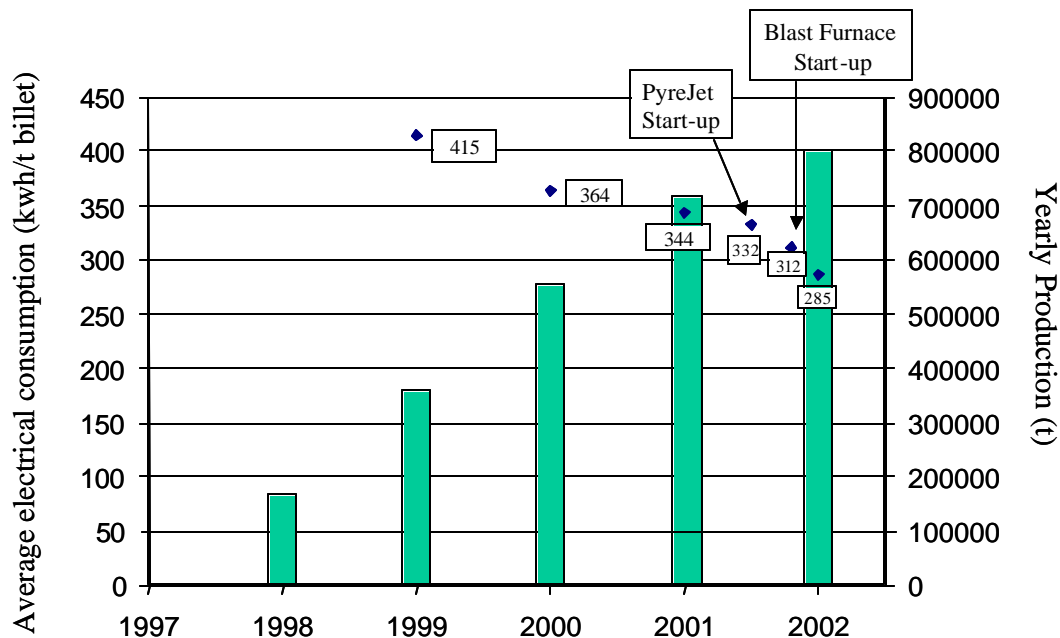


Fig 3: EAF history - JYXS

## 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 picture of PyreJet is shown in Fig. 4.



Fig 4: PYREJET™ assembly

### 3.2. PYREJET™: a complete package

The multi-function tool described above is the central piece of a complete package. The PyreJet™ burner and its associates control are the answer to the steelmaker concerns, which are :

- Reduce the conversion costs
- Increase the flexibility of the furnace
- Increase the productivity of the furnace
- Achieve a reproducible process through furnace automation
- Achieve high steel quality

PyreJet™ allows the implementation of steel making best practices, especially foaming slag practices. One key aspect of foaming slag practices is the variable control of the carbon injection flow rate.

Fig. 5 shows the HMI developed for the JiangYin Xing Cheng project. The carbon injection control (and in particular the variable flows) are integrated in the HMI, allowing operators to take advantage of the complete potential offered by the PyreJet™ technologies.

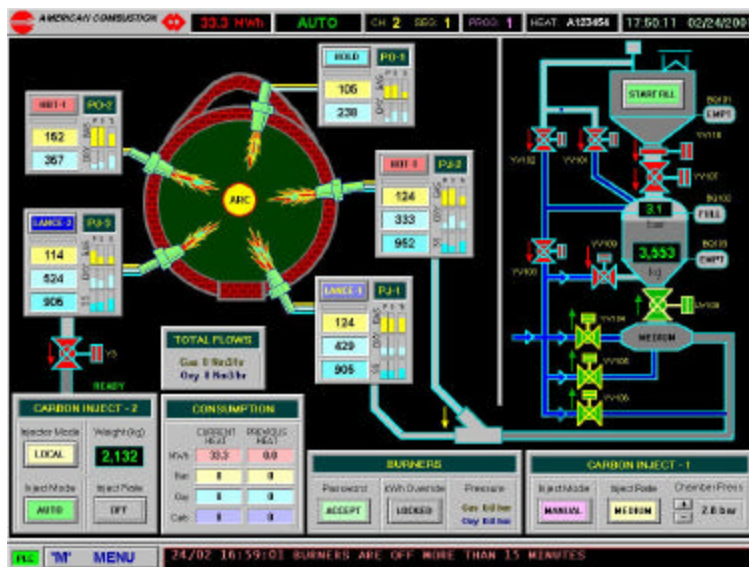


Fig 5: PyreJet™ and Carbon Injection Control Screen

### 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 detailed generic operating mode and metallurgical principle of PYREJET™ is described in [2] and [3].

#### From burner mode to lancing mode

At the beginning of each charge the PYREJET™ operates as a regular oxy-fuel burner heating the scrap located in the cold spots. After the scrap is preheated and partially melted in, soft lancing is started in order to cut scrap in the more remote areas and get access to the melt.

Aggressive oxygen lancing begins when both stages of carbon removal are kinetically feasible to prevent slag over-oxidation.

### **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.

### **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.

## **4. INDUSTRIAL RESULTS AT JYXS**

### **4.1. PYREJET™ Implementation**

The general arrangement of the PyreJet™ is shown on Fig. 6. The installation at JYXS consists in:

- Three PyreJets™
- Two Pyrox burners.

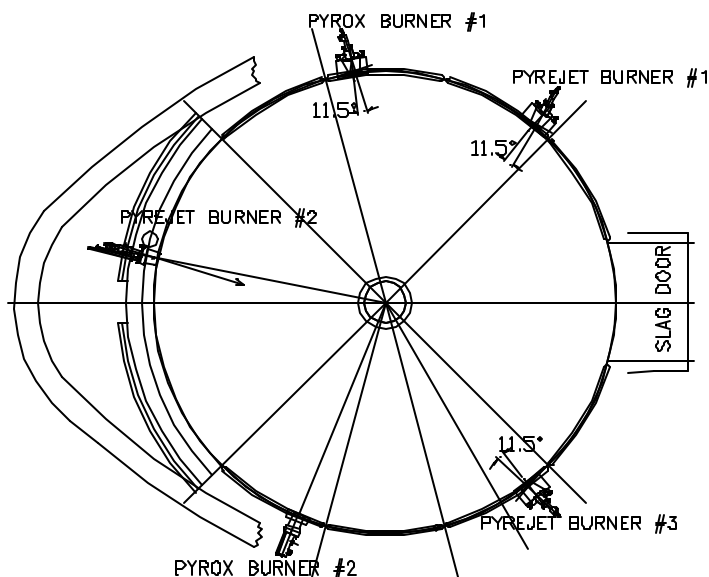


Fig 6: PyreJet locations on JYXS Electric Arc Furnace

Two PyreJets and two Pyrox burners are installed in the side walls of the furnace (Fig. 7a). One PyreJet is installed in the EBT area (Fig. 7b). All injection tools are oriented with an angle in order to avoid facing the electrode (Fig. 6).

The PyreJet and Pyrox are continuously operating in combination with the door lance to maximize oxygen injection capability at a given time when maximum performance and shortest heat time are required (see “productivity mode”, section 4.3).



(a) Side-wall installation at JYXS



(b) EBT installation (typical)

Fig 7: PyreJet installation on the furnace

## 4.2. Operating results

The scrap mix at JYXS typically consists of solid pig iron (up to 35%), heavy scrap (15-25%), and light scrap (30-40%).

Table 2 shows the comparison of the operating results before and after the implementation of the PyreJet™ technology. The data are averaged over 3 months period (2 months for the hot metal charging).

|   | <b>Before<br/>PyreJet™</b><br>(3 months) | <b>With PyreJet™</b>   |                           |
|---|--|------------------------|---------------------------|
|   |  | Aug, Sept, Oct<br>2002 | Nov. Dec.<br>2002         |
|   | 100 % scrap                              | 100% scrap             | 20% hot metal<br>charging |
| Weight of scrap charged<br>- excluding pig iron- (kg/t) | 738.1                                    | 743.8                  | 712.4                     |
| Electrical consumption<br>(kwh/t billet)                | 346                                      | 324                    | 285                       |
| Metallic Yield liquide/scrap)                           | 91.5                                     | 91.5                   | 92.1                      |
| Solid pig iron %<br>in the scrap mix                    | 32.5                                     | 29.4                   | 15.0                      |
| Liquid hot metal poured in<br>the furnace (%)           | 0%                                       | 2.6 %                  | 19.4 %                    |
| Propane/Butane mix<br>consumption, Nm <sup>3</sup> /t   |  | 1.25                   | 0.95                      |
| Oxygen consumption for<br>EAF, Nm <sup>3</sup> /t       | 46.8                                     | 51.9                   | 46.9                      |
| Electrode consumption, kg/t                             | 1.04                                     | 0.99                   | 0.95                      |
| Carbon consumption, kg/t                                | 7.6                                      | 6.4                    | 5.4                       |

Table 2: Average results of PyreJet™ at JYXS

Depending on the steel grades and the sections, the EAF operates in two modes. Mode one (“the economic mode”): the caster is the bottleneck and the furnace has to wait for the caster availability. In such mode, the main target of JYXS is savings, not productivity and power on time.

Mode two (“ the productivity mode”): the EAF is the bottleneck. For these operating conditions the main target is the power on time.

The results in Table 2 are the average of those two modes. The benefits of PyreJet™ technology – especially in terms of electrical consumption and power-on-time - are therefore underutilized due to the existence of the “economic mode”.

Table 3 presents the results of the “productivity mode”. 10 consecutive heats with and without PyreJet™ operation were selected for comparison.

| <b>“Productivity Mode”<br/>Steel Grade : 37Mn5</b> | <b>Without PyreJet™</b> | <b>With PyreJet™</b>     |
|--|-------------------------|--------------------------|
| Power on time, min                                 | 54.4                    | 45.3                     |
| Tap to tap time, min                               | 63.3                    | 52.4                     |
| Electrical Consumption,<br>kwh/t                   | 327                     | 319                      |
| Propane/Butane consumption<br>Nm <sup>3</sup> /t   | 0                       | 1.2                      |
| Oxygen consumption EAF<br>Nm <sup>3</sup> /t       | -                       | + 9.5 Nm <sup>3</sup> /t |
| Electrode consumption kg/t                         | 1.04                    | 0.99                     |

Table 3: PyreJet™ performances in "Productivity Mode" at JYXS

## 5. CONCLUSION

The PYREJET™ system played a major role in achieving major improvements by JYXS in the areas of conversion costs reduction and productivity increase. This technology allows for up to 17.5% reduction in power on time when productivity is of essence.

The start of the blast furnace made possible the charging of liquid hot metal in the EAF. The electrical consumption of the EAF equipped with PYREJET and utilizing 20% of hot metal in the charge is 285 kwh /tonne billet on average.

ACI and JYXS continue their cooperation in implementing innovative oxygen injection technologies %aimed at the increase of the portion of the hot metal in the charge up to 60%.

## REFERENCES

- [1] Further advance in EAF efficiency with Pyrejet™ burner injection by V. Shifrin, A. Popenov, L. Coudurier and M. Devaux, *STEEL TIMES*, Sept. 2001
- [2] PyreJet™ : a multi-function system for EAF steel making : Industrial Results at LME by JM Thebault, R. Cervi, L. Coudurier, M. Devaux, V. Shifrin and JC Vuillermoz, 7<sup>th</sup> *European Steel Making Conference*, May 2002, Venice, Italy.

[3] Implementation of PyreJet™ technology in EAF at Siderurgica Barra Mansa  
by V. Shifrin, A. Popenov, M. Grant, O. Delabroy, G. Cruz de Moraes, W. do Amaral Filho  
*60<sup>th</sup> EAF Conference*, Nov. 2002, San Antonio, USA

[4] Chemical Energy in EAF: benefits and limitations  
by S. Jepson, *2000 ISS Electric Furnace Conference*, Orlando, FL, USA, Nov. 2000

[5] Efficiency of oxygen technology in the EAF  
by M. Grant and B. Allemand, *2000 AISE Convention*, Chicago, IL, USA, Sept. 2000

[6] Optimization of oxygen technology in the EAF  
by M. Buffenoir, K. Tynelius-Diez, M. Devaux and J.E. Schindler, *STEEL TIMES*, Dec. 1997

[7] US Patent 4,622,007 Variable Heat generating method and apparatus

[8] US Patent ; 5,599,375 Method for electric steelmaking

[9] US Patent ; 5,788,921 Apparatus for electric steelmaking

[10] US Patent ; 5,858,302 Apparatus for electric steelmaking