AN IMPROVED METHOD OF APPLYING CHEMICAL ENERGY INTO THE EAF

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The industry trend for the introduction of oxygen into the EAF is via supersonic oxy-fuel sidewall burners / injectors. The PTI JetBOx™ enables the burners/injectors to be located in such a way that there is a much shorter distance for the jets to travel than normal. In addition the optimum angle of attack of both the burners and foamy slag carbon injection port can be achieved. This unique design results in an extremely high efficiency from the chemical energy input without operational problems. The advantages, theory, and practical operating results of several installations on both AC and DC furnaces in Europe, USA and South Africa are discussed.

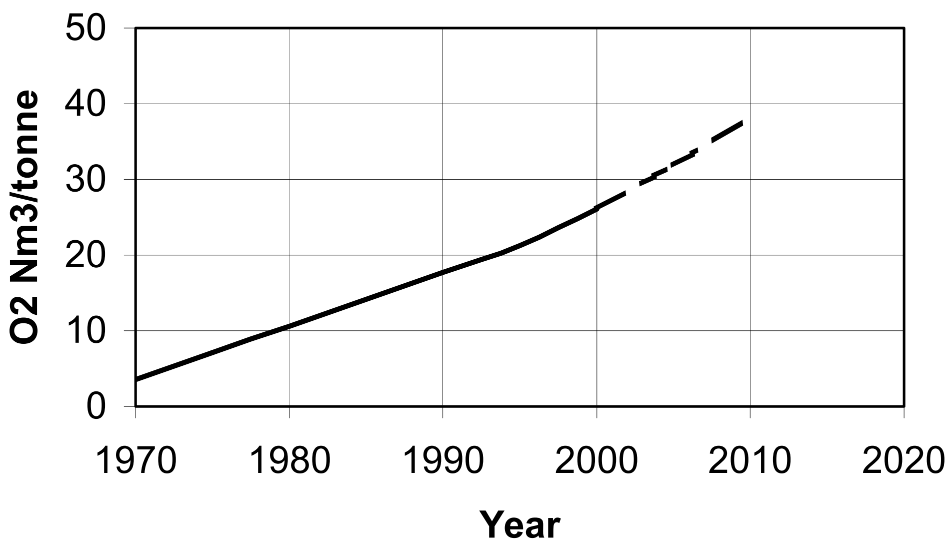
INTRODUCTION

The amount of chemical energy typically represents 25 to 35% of total energy consumption in EAF. Another important factor is that the method of chemical energy application significantly influences electrical arc heat transfer efficiency (i.e. quality of slag foaming, arcs stability etc).
Chemical energy consist of two main sources:

- fossil fuels supplied via oxygen – fuel burners
- lanced oxygen and carbon

Over the past three decades the average consumption of oxygen in (EAFs) has steadily increased (figure 1) and the forecast is for this consumption to continue to rise. Perhaps one day rather than talking about electric arc furnaces we will talk about combined energy furnace.

Figure 1 - Average oxygen consumption in EAF



Over the same period of time average transformer power has increased and tap-to-tap times have dropped considerably. This reduces the time available for efficient oxygen introduction and places higher demands on the new chemical energy system and it's operation. Significantly larger amounts of oxygen need to be injected per time unit and efficiency of this energy introduction plays a greater role in overall furnace efficiency.

These requirements have led to many recent advancements in the area of chemical energy systems, and the patented JetBOx[TM]technology, developed by PTI, has been proven to meet this need for increased chemical energy intensity whilst maintaining maximised efficiency and reliability.

JETBOX™ TECHNOLOGY BACKGROUND

In order to explain how The JetBOx™ technology works it is important to understand two key elements of its design. The first part of the technology is a combined burner / lance (PTI Jet burner) which has been proven in over 30 EAF's since 1995. The second part is the watercooled copper box that enables the burner/lance to be safely positioned in the optimum position.
The PTI Jet burner can work in three basic operating modes: burner, soft lance and supersonic shrouded oxygen lance.

Description of these modes and flame examples are shown in table no.1

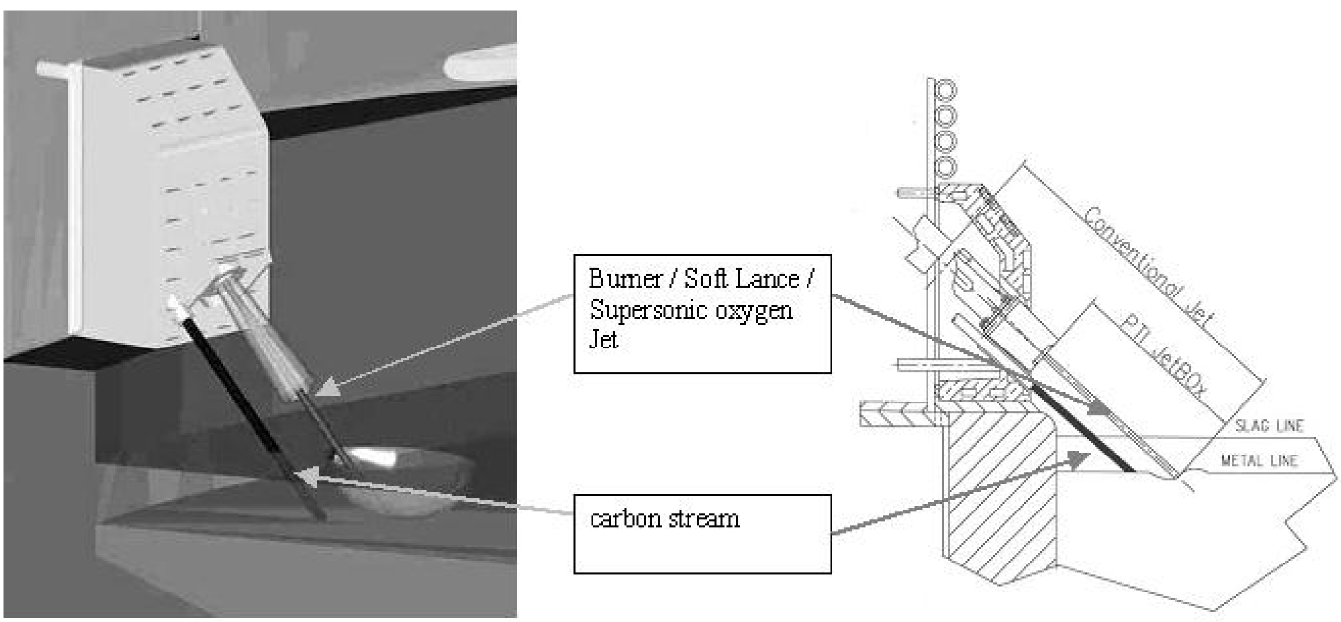
Table 1 – Operating modes of PTI Jet burner

Operating mode	Function	Flame example
Hot fire – multiple flame structure highly efficient oxy-fuel flame (up to 6 MW)	Scrap preheating and melting Two stage combustion flame	
Soft lance – piercing, oxygen rich flame	Scrap cutting with rigid oxygen stream – middle Post combustion CO with soft oxygen – oxygen rich softer envelope	

SS lance – Mach 2 – supersonic shrouded oxygen injector (up to 55 Nm3/min oxygen flow)	Decarburisation, energy introduction and bath agitation Supersonic jet stream – middle Oxy-fuel flame shrouding Post combustion of CO with excess of oxygen	

It is well known that using of shrouding flame around supersonic oxygen stream significantly prolongs jet coherency as can be seen from flame example in table 1. The PTI Jet burner has had such a function since 1995. However, the fundamental laws of physics state that the oxygen speed and its ability to penetrate a liquid bath reduce with distance from the burner tip, even if shrouding flame is applied. Therefore, it is desirable to reduce distance from nozzle to liquid bath, which the oxygen has to travel, while keeping a good angle of penetration. The same logic applies to carbon injection – to obtain high carbon efficiency it is necessary to inject carbon close to the bath and with relatively steep angle. To achieve this philosophy the second part of JetBOx™ technology is used – the water cooled copper box, the JetBOx™. Figure no. 2 shows the principal of its operation.

Figure 2 – JetBOx™ principle



The copper box is designed for long life, with the ability to withstand the impact of falling scrap, while at the same time provide excellent cooling. The box is located just above the last course of refractory brick with the front face about in line with the hot face of the brick. This location provides the following advantages:

- The burner/lance device is located low in the furnace, which promotes better heat transfer to the scrap while the burner is in the scrap-melting mode.
- The angle is such that splash from the electrodes or from scrap charging will not block the gas and oxygen orifices inside the combustion chamber (less plugging).
- Supersonic oxygen efficiency is maximized due to the oxy-fuel flame shrouding combined with relatively short jet length and the ability to use the optimal jet attack angle.
- Efficient oxygen use means less electrode oxidation.
- Refractory problems in the jet/bath area are minimized since a) the reaction zone is relatively far away from the brick face and b) additional refractory cooling by water-cooled copper box directly contacted with refractory
- Injection carbon is applied close to the bath, parallel with the flame/jet, which promotes a better foamy slag and minimizes carbon loss. It also provides the best recarburization of steel, if required.
- The oxidation of iron to the slag is minimized due to the better bath stirring produced by the jets, and the ability to employ several reaction sites.

Scrap melting, post combustion and decarburization can be accomplished with the door closed most of the time, which yields significant energy savings.

PRACTICAL RESULTS

More then 10 steelworks have invested in the JetBOx™ technology since the first installation in November 2000. The following describes equipment employed and the results obtained at four of these companies: Huta Zawiercie (PL), Nucor Steel Hickman (USA) and Gallatin Steel (USA) and Iscor Long Steel products (RSA)

HUTA ZAWIERCIE

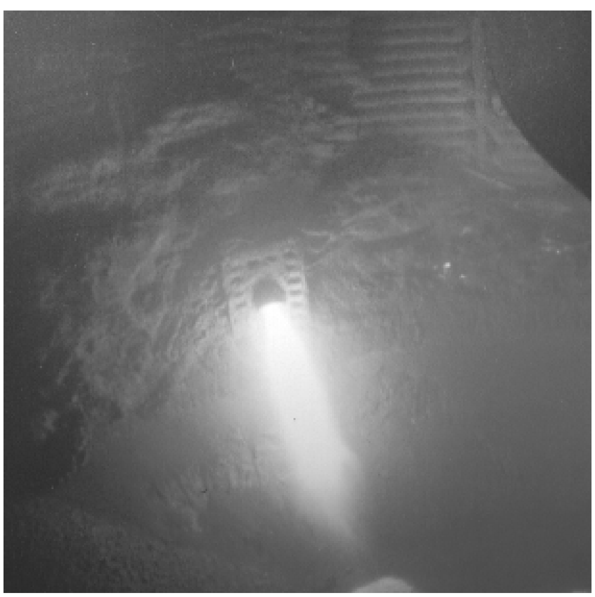


Fig. 3
The JetBOx™ promotes good water-cooled panel slag coverage which helps prevent the panel from overheating.

This system with 4 JetBOx™ units replaced a conventional three burner system and slag door lance manipulator

The installation resulted in a 20% powen time savings and a reduction in taptotap time of 22.5%. These results were achieved from the additional chemical energy introduced by the system and from the increased electrical power input. Because the system improved the slag foaming on the furnace, a longer arc could be used without damaging the sidewall panels.

The JetBOx™ mounting configuration promoted good a slag coverage of the wall by moving the hot flame towards the center of the furnace. The water-cooled panel adjacent to the oxygen reaction zone receives a higher radiative heat flux and good slag coverage is important to protect the panels from overheating. (Figure 3)

Huta Zawiercie operates with light scrap and a 3 to 4 bucket charge operation. The light scrap would often cause skulls to hang on the sidewall that would sometimes fall into the bath during the refining period and cause carbon boils and temperature loss. The JetBOx™ installation allowed the scrap to melt evenly and eliminated any major skulls on the water-cooled sidewall. This also allowed for earlier scrap charging and less scrap delays.

Before the installation of the JetBOx™ system, Huta Zawiercie's previous practice required the use of iron ore to achieve low carbon melts. This was because of an inefficient oxygen practice and high sulfur (sulfur was up to 0.15% on occasion). After the installation of the system this was no longer necessary.

The system showed excellent results for oxygen acceptance. Electrode consumption was reduced by 24%, and no noticeable negative results on refractory consumption were noticed. Even at their close proximity to the bath, the burners were reported to show little to no plugging.

Table 2 - Huta Zawiercie - 3 to 4 Bucket Operation Results

	Unit	Base*	PTI**	% Change
Tapping Weight	t	133,5	133,5	0,0%
Power Input	MW	60,5	66,5	9,9%
Secondary Voltage	V	857	909	6,1%
Electrical Consumption	Kwh/t	480	415	13,5%
Tap to Tap Time	Min	88	68,2	22,5%
P.O.T.	Min	63,7	51	19,9%
Natural Gas Consumption	Nm^3/t	2,7	5,4	100,0%
Oxygen Consumption	Nm^3/t	28	32,3	15,4%
Slag FeO	%	35 - 45	25 - 40	20,0%
Electrode Consumption	kg/t	2,3	1,8	21,7%

* Original Installation - 3 Burners and Slag door Manipulator
**PTI installation - 4 JetBOxes

NUCOR STEEL – HICKMAN

The primary target at Nucor Steel Hickman 150 t DC furnace was to replace all moving lancing equipment by fixed installation to reduce maintenance cost, improve foaming slag and enable safe, automatic closed door operation. Intensity of chemical should not increase and no production increase is required at the moment. The original chemical energy equipment included two sidewall water cooled lances inclined at 50° and with 67 Nm3/min oxygen flow each, and water cooled slag door lance installed on manipulator. This equipment has been replaced by 4 JetBOx™ systems and is not used any more. Even if the original chemical energy program is conservative, the system show promising results for the future. The improved oxygen efficiency is reflected in lower FeO in the slag – in spite of very low tapping carbon (<0.03%), lower total carbon consumption and significantly improved yield confirmed by results of more then 100,000ton of liquid steel produced with JetBOx™. Additional significant benefit is lower maintenance cost of the system. JetBOx™ design enable trouble free operation with minimum requirements of consumable parts. The variable costs and maintenace costs savings pays back for the JetBOx™ system in less than 6 months. These encouraging results lead Nucor to plan installation of the JetBOx™ system on the second furnace and further focus on increased chemical energy intensity when market conditions enable efficient utilization of potentially increased production.

A summary of initial results is provided in table 3, below.

Table 3 – Nucor Steel Hickman Results

FeO % in a slag	Decreased 6%
Yield	Increased 2%
Power on time	Decreased 4%
Carbon injection consumption	Decreased 14%
Oxygen consumption	no change

GALLATIN STEEL

Gallatin is one of the largest DC Arc Furnaces in the world. They have a twin Shell DC EAF operation. In December of 2001, PTI installed two JetBOx™ systems in one shell while the other remained unchanged. This allowed for a true comparison of the different chemical energy systems. The first heat produced with the PTI JetBOx™ was completed on Monday December 10th 2001. The following summary shows the results after the first campaign. The initial firing program is conservative but demonstrates excellent results so far. Further improvements to the results are expected as a step-by-step approach is followed to optimise the oxygen consumption for their process. The initial requirement by Gallatin was to remove the need to use the door lance pipe manipulator. This would save the cost of consumables and maintenance. Also, eliminating the lance pipe manipulator would allow the slag door to be kept closed for increased safety and energy savings. This was accomplished after two weeks of operations. Furnace parameters are summarised below:

- Average electrical input 110 MW
- Furnace Tap weight 172 metric tons
- Twin shell single power source (switch from shell to shell)
- Copper water cooled panels

- Product – thin strip
- Ave. tapping carbon 0.03 %. Active oxygen about 850 ppm
- Single charge per heat using approximately 23 % pig iron and 15% HBI
- Average approximately 24 heats per day
- Typical Power on time (POT) 48 minutes
- Previous oxygen equipment – slag door manipulator with 2 consumable lances 3400 Nm^3/h each of oxygen flow.
- Installed now -two (2) PTI JetBOx™ systems @ 4.5 MW capacity and 2550 Nm^3/h oxygen each.
- Carbon injection has two points - through JetBOx™ and through the roof.

Initial Results after 2 months operation are summarised in table no. 4

Table 4 – Gallatin Steel results

Description	Unit	Before	After	diff.	diff. %
Tapping Weight	**t**	**172**	**172**	**0**	**0,0%**
Power Input	**MW**	**110**	**110**	**0**	**0,0%**
Tap to Tap Time	**Min**	**52,2**	**50,8**	**-1,4**	**-2,7%**
Power on Time	**Min**	**47,4**	**45,9**	**-1,5**	**-3,2%**
Secondary Voltage	**V**	**865**	**865**	**0**	**0,0%**
Electrical Consumption	**Kwh/t**	**448**	**421**	**-27**	**-6,0%**
Natural Gas Consumption	Nm^3/t	**0**	**2,5**	**2,5**	**-**
Oxygen Consumption	Nm^3/t	**29,6**	**22,0**	**-7,6**	**-25,7%**
Electrode Consumption	**kg/t**	**1,79**	**1,67**	**-0,12**	**-6,7%**
Carbon bulk	**kg/t**	**5,6**	**3,6**	**-2**	**-35,7%**
carbon injected	**kg/t**	**9,1**	**6,1**	**-3**	**-33,0%**
Yield	**%**	**92,6**	**94,1**	**1,5**	**1,6%**

As can be seen in the table, productivity improvements and significant savings of both power and electrodes have been achieved despite the lower oxygen consumption. Yield is up by 1,5% which demonstrates the excellent oxygen efficiency of the JetBOx™ system. Bulk carbon efficiency increased and injected carbon consumption reduced while foaming slag quality was significantly improved.

Apart from the obvious improvements of all major operating parameters, quality benefits were also observed. Closed-door operation has been reflected in the lower nitrogen levels– average nitrogen content is down by 7 ppm.

Results so far also indicate refractory savings and leeway for an increase in oxygen consumption allows for future additional reduction in electrical energy.

ISCOR LONG STEEL PRODUCTS

This South African steel producer installed 2 JetBOx™ systems and one EBT located PTI Jet burner to replace consumable slag door lance manipulator on their 60 t AC EAF. Location of the boxes and burner is obvious from figure no.4, which also represent typical user interface for the system.

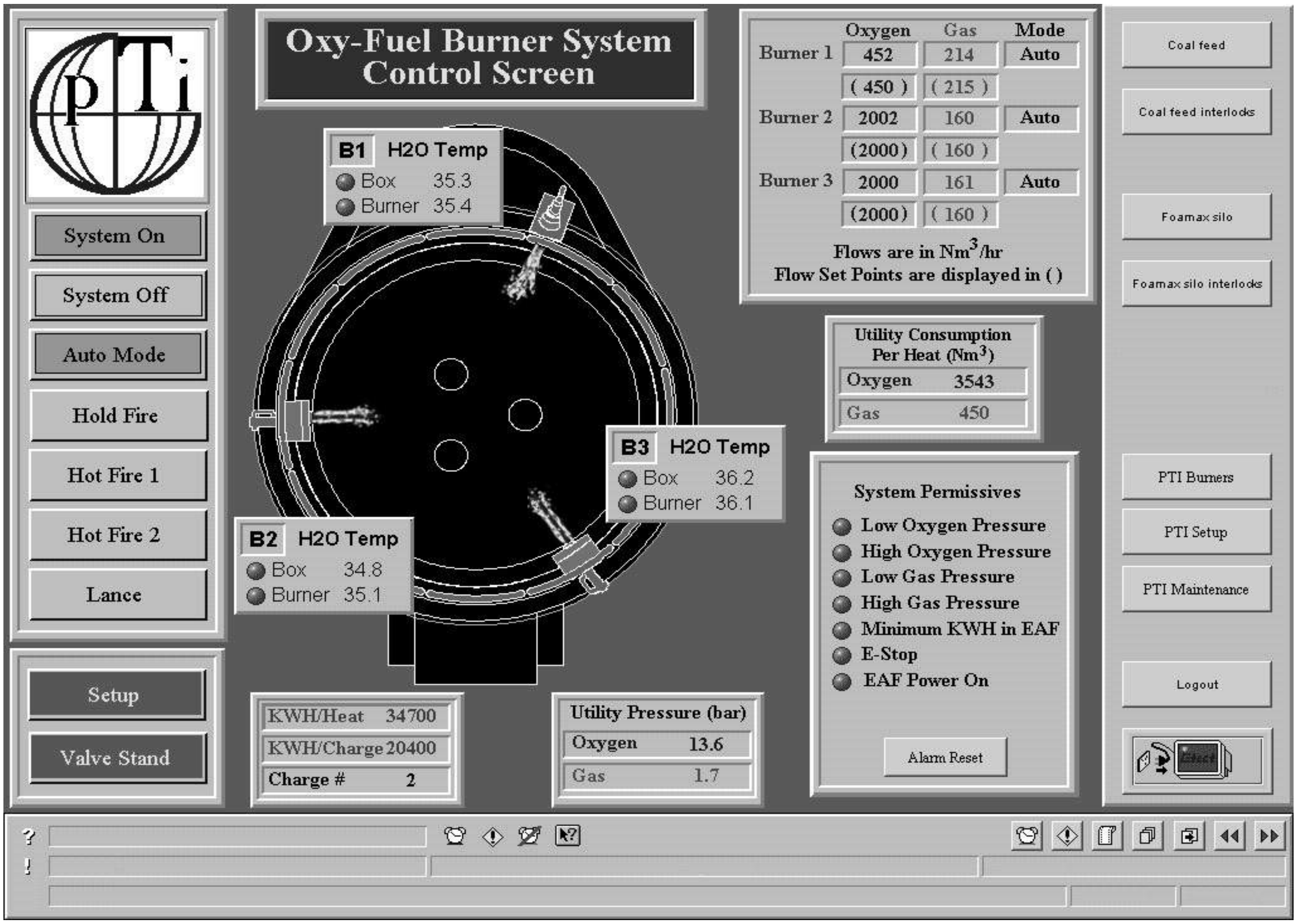


Fig. 4 – user interface with location of boxes and burner at ISCOR

Furnace parameters are summarised below:

- Average electrical input 44 MW
- Furnace Tap weight 60 metric tons
- Three charges per heat
- Typical Power on time (POT) before JetBOx™ - 38 minutes
- Previous oxygen equipment – slag door manipulator with 2 consumable lances
- Installed now -two (2) PTI JetBOx™ + one EBT located PTI Jet burner
- Carbon injection - through JetBOx™.

The system is in operation since May 2000 and significant process improvements have been achieved. Lance manipulator has been completely eliminated, operation has been automated and standardised. Significant benefits have been realised in power on time, electrode and electricity savings. The summary of key performance indicators is in table no.5

Table 5 – JetBOx™ system results at ISCOR

Item	**Change**
Power on time	- 6 minutes
Oxygen consumption	+ 10 Nm3/t
Fuel consumption	+ 0.19 GJ/t
Electrode consumption	- 0.25 kg/t
Electrical energy consumption	- 65 kWh/t

CONCLUSION

The JetBOx™ system is well proven patented technology installed on many different furnaces with excellent results. The JetBOx™ system takes fixed sidewall shrouded supersonic oxygen injection to the next step by utilising innovative location for safely installation of combined burners / lances closer to the molten metal in EAF. This location also enables efficient carbon injection with improved efficiency reflected in better yield and improved foaming slag practice. The JetBOx™ durable design ensures long life, low maintenance and high reliability confirmed by more than 30 boxes in operation by now. As for most of the good steel making technologies – simple idea delivers great benefits when properly applied to the practice.

ACKNOWLEDGMENTS

The authors would like to thank all of the personnel at Nucor, Huta Zawiercie, Gallatin Steel and Iscor, who contributed to successful JetBOx™ implementation on their furnaces and also provided valuable data and information used in this paper.