The JetBOx™ burner/injector system for EAF steelmaking

JetBOx is a combination oxygen injector/burner system to increase the chemical energy input to all designs of EAFs, resulting in improved furnace productivity and lower conversion costs. More than 50 installations are now in use.

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Chemical energy plays an important role in EAF steelmaking. This energy is delivered by the oxidation of fossil fuels, exothermic reactions of chemical elements such as iron, carbon, manganese and silicon, and also by post combustion of carbon monoxide in the upper shell. Process Technology International (PTI), Inc. has invented and patented the JetBOx supersonic oxygen injection system, which fulfils all the functions of an integrated chemical energy tool. The JetBOx system increases EAF productivity and reduces conversion costs. This has been achieved by developing a unique, efficient method of chemical energy introduction for each individual meltshop. As each system installation was optimised, the JetBOx system evolved to meet the different demands of each meltshop. It has been installed in EAFs utilising batch scrap charging, the ConSteel™ process, DRI and hot metal operations with equally good results. Since 2001, JetBOx systems efficiently and safely operate at over 50 different steel facilities meeting the challenge presented at each individual mill.

TECHNOLOGY DESCRIPTION

Chemical energy tools for the EAF have evolved over the years, starting from manually held oxygen pipes, and progressing to slag door manipulators (with both consumable and water cooled lances), sidewall burners, and post combustion injectors. The benefits of chemical energy introduction continued to increase during this development.**[1]** Nowadays modern chemical energy systems integrate all these functions in one tool.

The first phase of fixed sidewall oxygen injection was the gas-shrouded, oxygen injector that eliminated the need for complicated positioning mechanisms. By shrouding a supersonic stream of oxygen with subsonic gas, the distance the oxygen stream remained supersonic from the tip of the nozzle greatly increased.**[2]** With proper shrouding, supersonic oxygen streams could penetrate the steel bath from as far away as 2m.**[3]** This allowed the oxygen injector to be located in a fixed position on the furnace sidewall without the need for large and complicated positioning mechanisms, and still deliver oxygen to the steel bath at efficiencies as good as, or better than, retractable oxygen injection lance systems. Injecting oxygen with a gas shroud increased the efficiency of oxygen injection and eliminated the cost of maintaining a large positioning mechanism on the EAF deck.**[4]**

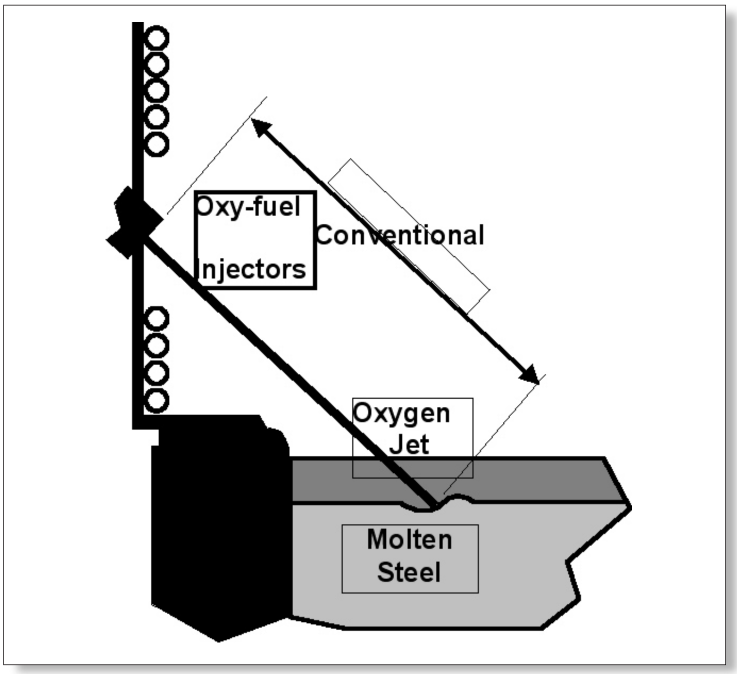

Fig.1 Conventional placement

The first gas-shrouded injectors were placed high on the furnace sidewall and were only installed in 100% scrap charged furnaces. The next step in the evolution of gas shrouded oxygen injection systems is the JetBOx system.

JETBOX TECHNOLOGY

Burner placement While the first gas shrouded oxygen injection systems eliminated the need for complicated lance positioning devices, the injector was moved farther away from the steel bath, as seen in *Figure 1*. Since the gas shroud increased the effective length of the injected ▷

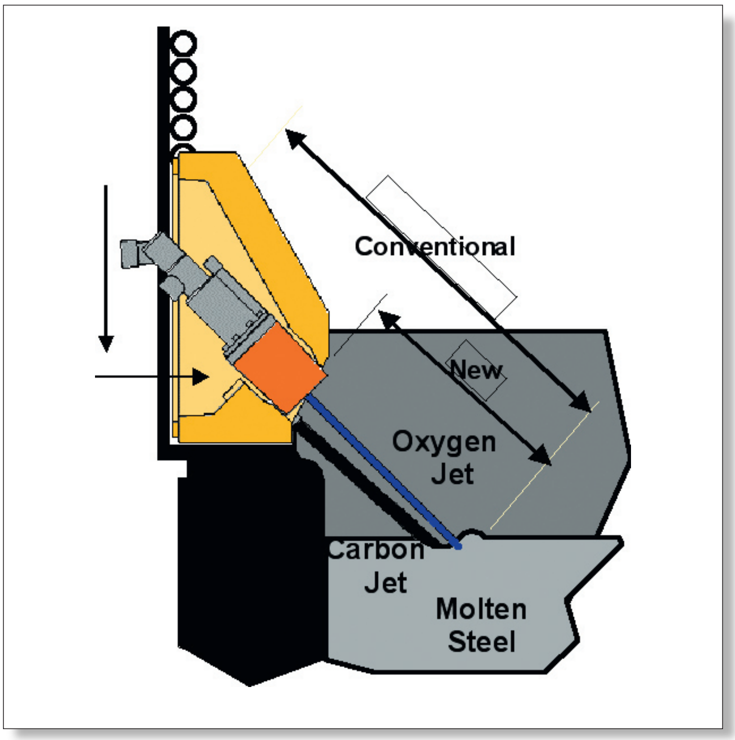

Fig.2 JetBOx™ placement

oxygen, placing the injector farther away from the steel bath was, at first, not a big problem. The first gas shrouded oxygen systems showed operational improvements over the floor mounted systems. However, the closer the oxygen injection is moved towards the steel bath, the more efficient the injected oxygen becomes.

PTI was the first company to move the oxygen injection point directly over the steel bath as shown in *Figure 2* which allowed the oxygen injector to be moved down and into the furnace until it was directly over the sidewall refractory. By shortening the distance to the hot metal (see *Figure 3*), the new design allowed the oxygen to achieve the best efficiency and give the best productivity at the lowest cost to the steel producer.

Another benefit of moving the burner/injector out into the furnace is that the chemical energy injected into the furnace is moved away from the water-cooled panels. This decreases the risk of damage to the burner/injector and water-cooled panels due to splashing or flashback. While the injector was moved out and into the furnace, there is no fear of damage during the scrap addition. The JetBOx is made of water-cooled copper and the front is angled to direct falling scrap away from the burner face.

Multifunctional injector/burner Many plants have installed separate chemical energy burners and oxygen injection equipment on their EAFs. PTI has combined these two pieces of equipment as supersonic oxygen and chemical energy from fuel are not needed at the same time during EAF operation; energy from fuel is needed when solid scrap is present in the furnace and supersonic oxygen injection is needed during flat bath operation.

The system is designed to:

- Deliver over 4.5MW of chemical energy to the scrap during the early stages of melting
- Transition to higher volume, low velocity oxygen during the middle stage when semi-solid scrap is still present
- Finish with high velocity supersonic oxygen when a flat bath is achieved

Description	Unit	Before	After	Difference
Tapping weight	t	70	70	0
Power input	MW	28	28	0
Tap-to-tap time	Min	60	56	-4
Power-on time	Min	50	46	-4
Power-off time	Min	10	10	0
Electrical consumption	kWh/t	330	276	-54
Fuel(natural gas)	Nm^3/t	0	0	0
Oxygen consumption	Nm^3/t	50	46	-4
Electrode consumption	kg/t	3.7	3.6	-0.1
Carbon bulk	kg/t	0	0	0
Carbon injected	kg/t	5	5	0
Scrap	kg/t	700	700	0
DRI + HBI	kg/t	0	0	0
Shredded scrap/pig iron	kg/t	0	0	0
Hot metal	kg/t	410	410	0
Kohle model	kWh/t	258	266	8

Table 1 Daye Steel AC furnace summary

Since JetBOx delivers the functionality of several different devices, the need for several different control trains is eliminated hence reduces the overall cost of the project.

Single oxygen control line The evolution of the JetBOx system continued with the elimination of the need for two oxygen control lines. Traditional gas shrouded oxygen injection systems need two oxygen lines. One line controlled the oxygen delivered to the shroud fuel and one delivered the supersonic oxygen to the injector. The patented burner design uses a bypass valve to deliver the correct amount of shroud oxygen during supersonic operation mode. The bypass oxygen is tailored to each plant and is driven by the operational needs of each EAF. The elimination of one oxygen line also eliminates the need for a separate oxygen control train and thus greatly reduces the cost of installation, capital and maintenance costs while improving the reliability of the injectors.

Optimal carbon injection Most plants used their floor mounted oxygen lance mechanism to deliver carbon to the slag as well as inject carbon into the bath. However, when the lance mechanism was eliminated, the carbon injection was usually positioned parallel to the new gas shrouded oxygen injection location, which was usually placed high on the furnace wall. This new position caused a problem because carbon injection is even more sensitive to travelling large distances than unshrouded oxygen. Since shrouding oxygen increases the effective length of the stream, it was reasonable to assume that shrouding carbon would produce similar results. Unfortunately, the shrouding of the carbon is not an effective method for improving this characteristic. Several carbon injection methods used in EAF operation resulted in uncontrolled carbon dispersion into the furnace or poor utilisation of the carbon for FeO reduction. Carbon, which is introduced with these methods, is inefficiently consumed, resulting in higher off-gas heat loads and higher carbon consumption.

The JetBOx moves the carbon injection source beneath the slag surface near the oxygen injection point and minimal carbon is lost to the exhaust system, or consumed above the bath. Most importantly the carbon is introduced where it is needed the most. The system injects the carbon and oxygen streams parallel or slightly angled to each other. With parallel direction, the Bernoulli convection generated by the oxygen stream will entrain the carbon stream in its dense phase to ensure that it is delivered to the slag metal interface. Changing the angle between the oxygen and carbon streams controls the degree of Bernoulli convection.

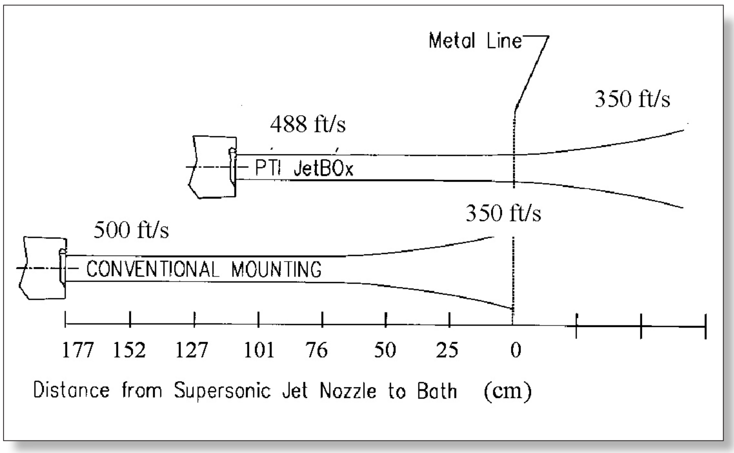

Fig.3 **Oxygen stream bath penetration comparison**

Description	Unit	Before	After	Difference
Tapping weight	t	75	75	0
Power input	MW	37	37	0
Tap to tap time	Min	60	56	-4
Power-on time	Min	55	41	-14
Power-off time	Min	10	10	0
Electrical consumption	kWh/t	350	296	-54
Fuel(natural gas)	Nm^3/t	0	0	0
Oxygen consumption	Nm^3/t	50	45	-5
Electrode consumption	kg/t	1.4	1.2	-0.2
Carbon bulk	kg/t	0	0	0
Carbon injected	kg/t	6	6	0
Scrap	kg/t	700	700	0
DRI + HBI	kg/t	0	0	0
Shredded scrap/pig iron	kg/t	0	0	0
Hot metal	kg/t	410	410	0
Kohle model	kWh/t	258	269	11

Table 2 **Daye Steel DC furnace summary**

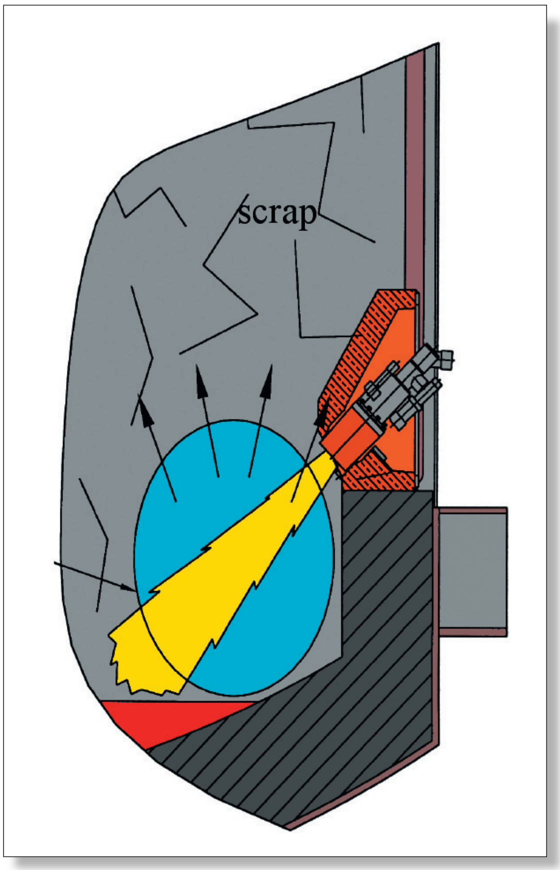

Fig.4 **Schematic of JetBOx™ operation at Shanghai No.5**

With the JetBOx, carbon is injected close to the oxygen reaction site and between the oxygen stream and the sidewall. This close proximity allows for precise control of the FeO reaction and increases the predictability of decarburisation and the tap carbon content. Injecting the carbon between the reaction site and the refractory reduces the FeO concentration in the vicinity of the refractory and helps prevent brick oxidation and wear.

OPERATION EXAMPLES FROM CHINA

Daye Steel – hot metal operation Daye Steel operates two EAFs – one AC and one DC furnace. Initially both furnaces operated with a water-cooled slag door lance. As there is no fuel available at Daye Steel, PTI designed special shrouded oxygen sidewall injectors integrated in the three JetBOxes installed in each furnace. Daye Steel charges around 40% hot metal. It is here, when hot metal is used in the EAF, that the JetBOx system is most effective. The burner quickly clears a path through the scrap to the steel bath then efficient oxygen injection quickly reduces the carbon in the hot metal while adding energy to the steel bath. Because it is so efficient at adding oxygen to the bath, it is also efficient at decarburising the steel, which improves process times and reduces kWh usage.

An issue at Daye Steel, as with many EAF operators that utilise hot metal in the process, is the lack of shrouding fuel. Some plants do not possess the capability to deliver any type of fuel – natural gas, LPG, diesel fuel, coal gas, etc – to the furnace. In these cases, the JetBOx system has adapted the oxygen injector to run efficiently without a shroud gas. While the ability of non-shrouded oxygen injection to decarburise the hot metal is not as efficient as a shrouded oxygen stream, the improvements to the process over traditional floor or high sidewall mounted oxygen lances is still significant.

The operating results before and after JetBOx system installation are summarised in *Tables 1* and *2* for AC and DC respectively. The electrical consumption is compared to the EAF energy consumption model

Description	Unit	Before	After	Difference
Tapping weight	t	103	103	0
Power input	MW	48	48	0
Tap to tap time	Min	72	68	-4
Power-on time	Min	54	50	-4
Power-off time	Min	18	18	0
Electrical consumption	kWh/t	431	392	-39
Fuel(natural gas)	Nm^3/t	0	6	6
Oxygen consumption	Nm^3/t	50	45	-5
Electrode consumption	kg/t	1.35	1.3	-0.05
Carbon bulk	kg/t	0	0	0
Carbon injected	kg/t	6	6	0
Scrap	kg/t	1,100	1,100	0
Kohle model	kWh/t	395	394	-1

Table 3 **Shanghai No.5 DC furnace summary**

developed by S Kohle.[5] Energy consumption and consequently productivity results before use of JetBOx were signiffcantly higher than predicted by the model. After installation, the energy consumption is almost in line with predictions by the Kohle model.

Shanghai No.5 Shanghai No.5 operates a 100t DC EAF with 100% scrap charge. Before JetBOx installation, the furnace was equipped with a water-cooled slag door lance and two water cooled sidewall lances and to increase efficiency of the melting process and improve productivity, four JetBOxes were installed, each one with a combined jet burner/injector. The capacity of each burner is 4.5MW and 2,100Nm^3/h of supersonic lance oxygen.

Chemical energy is introduced in the form of fuel combustion, oxygen lancing and carbon injection. The time and duration of introduction as well as the flow rates determine how much energy is introduced into the process. The location and direction in which the energy is introduced defines how useful and efficient is the chemical energy. By optimising the location, direction and time of implementation, more fuel, oxygen and carbon can be used at a higher efficiency.

JetBOx puts the chemical energy source directly under the scrap pile. This location, low in the furnace shell, eliminates the need to penetrate though the scrap, or travel long distances before becoming effective in this region of the furnace. The inward position of the burner injector in front of the furnace refractory allows the injection angles to be increased for ideal impingement of the oxygen and carbon streams. Due to increased hot gas residence time and scrap surface area available for preheating, the process efficiently accepts the chemical energy introduced into the furnace in this location. The energy introduced in goes directly to heating the scrap and avoids the negative effects commonly found with systems mounted higher on the furnace sidewall (see *Figure 4*).

The operating results before and after JetBOx installation are summarised in *Table 3*. As in the first case the energy consumption and consequently productivity results before PTI JetBOx system were significantly higher than predicted by the Kohle model. After installation the energy consumption is fully in line with prediction.

CONCLUSION

The EAF process accounts for about 40% of the worlds steel supply and is producing all types and levels of quality steel.[6] The JetBOx oxygen injection is installed at more than 50 EAFs worldwide with excellent results. The operations include hot metal charge furnaces, scrap operation as well as DRI charging furnace. The JetBOx system with no shrouding fuel, has demonstrated the efficient use of oxygen when coupled with a hot metal charge. **MS**

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JetBOx™ is a registered trademark of Air Products

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