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PTI SwingDoor™: operational results at a leading company in Middle East

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A leading company in Middle East (C.M.E.) commissioned an automatic sealing slag door (SwingDoor™) system without door burner supplied by INTECO PTI on an Electric Arc Furnace (EAF), operating with approximately 80 % cold Direct Reduced Iron (DRI). This installation represents one of the first industrial applications of automated sealed slag door technology in a DRI-dominant furnace, whereas prior global references were primarily scrap-based.

The project aimed to enable closed-door melting practice, improve slag retention and reduce air ingress. Initial commissioning identified several operational and design constraints which were resolved by subsequent engineering modifications. Following operational stabilization, validation during the Performance Guarantee Test (PGT) confirmed measurable improvements, which were determined to be even better than previously calculated, in:

- Electrical energy reduction
- Electrode consumption reduction
- Metallic yield increase
- Flux consumption reduction
- Slag generation reduction

This paper documents installation constraints, commissioning learnings, operational performance, and future enhancement opportunities including slag level prediction and automated de-slagging optimization.

KEYWORDS: SWINGDOOR™; SLAGDOOR; ELECTRIC ARC FURNACE (EAF); CLOSED-DOOR OPERATION; SLAG MANAGEMENT & RETENTION; DIRECT REDUCED IRON (DRI); ENERGY & EKECTRODE CONSUMPTION REDUCTION; AUTOMATED DE-SLAGGING.

INTRODUCTION

Electric Arc Furnace steelmaking is undergoing structural transformation driven by decarbonization, scrap scarcity, and increasing utilization of alternative iron sources such as DRI and HBI.

High-DRI operations introduce unique slag management challenges, especially low DRI/HBI grade with higher gangue content, increased slag volumes, lower yield and more iron losses during de-slagging process.

One basic limitation of the conventional slag door lies in its poor control of de-slagging especially with higher slag volumes. Consequently, there is always a risk of metal seeping through the "V" channels formed on the slag door breast.

DESCRIPTION OF THE CHALLENGE

In DRI based EAFs, the generated slag quantities are

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higher compared to scrap-based furnaces due to high DRI gangue content and the need to provide enough flux to neutralize the acidic content. Typically, DRI with higher gangue content requires bigger quantities of basic fluxes. Due to the large volume of slag generated, it is continuously discharged through the slag door tunnel—via a partially open conventional slag door—throughout the heat. This continuous flow ensures that the slag door tunnel remains free of scrap and cold slag.

As the door is permanently open, energy is lost and DRI-fines are partly lost through the continuous de-slagging as well resulting in loss of metallic iron through slag discharge and lower yield.

Fig.1 - C.M.E. original slag door.

DESCRIPTION OF THE PROJECT

In order to increase the overall furnace efficiency C.M.E., one of the leading companies in the Middle East in 2024, aimed to change the above described open slag door to closed-door melting practice in one of their EAFs with a capacity of 110t/heat and 1.1MT/Y capacity, which is charged with ~ 80-85% cold DRI (CDRI).

C.M.E. estimated that the closed-door operation will increase the furnace efficiency by the ability to retain slag and reduce air ingress. At the same time, it should increase operator safety. After validation of available technologies on the market, the INTECO PTI SwingDoor™ was figured out as the most suitable one.

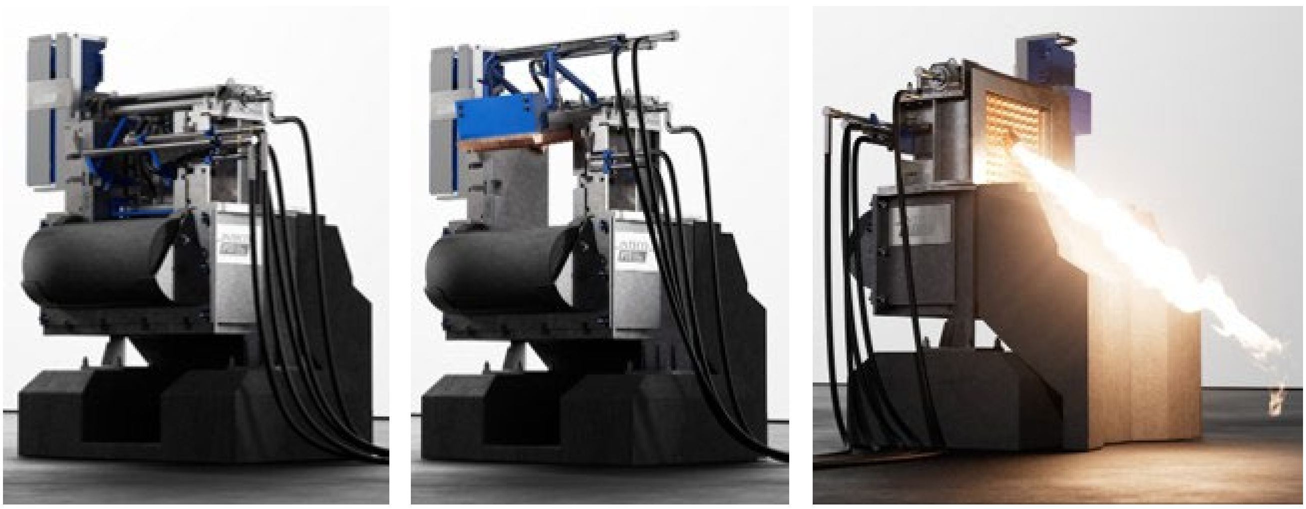

Fig.2 - PTI SwingDoor™ Outside concept view.

INTECO PTI reviewed the current operational performance of the existing furnace at C.M.E. and calculated the following expected measurable improvements from the installation of the SwingDoor™:

- electrical energy reduction ≥ **6,5 kWh/t**;
- electrode consumption reduction ≥ 0,025 kg/t;
- metallic yield increase ≥ 0,8 %;
- flux consumption reduction ≥ 1,4 kg/t;
- slag generation reduction ≥ 10 kg/t;

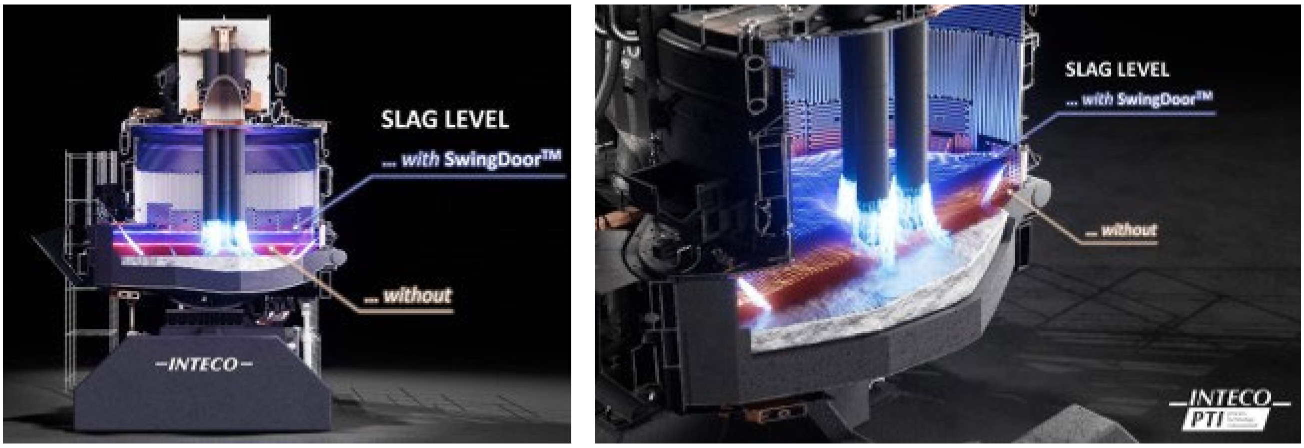

Fig.3 - Different slag level with SwingDoor™ operation.

DESCRIPTION OF THE SWINGDOOR™

The INTECO PTI SwingDoor™ is designed for modern EAF operation to better control the de-slagging process. The system is specifically designed to allow the EAF to be operated with a closed slag door which notably improves operational efficiency. The main operational function of this device is to control the amount of slag and increase the slag retention time inside the furnace which enhances the arc stability and improves the yield of raw material and fluxes. The SwingDoor™ is mounted on the upper shell in-line with the other water-cooled panels to eliminate the need for the slag door tunnel and therefore, prevents semi-molten scrap/slag from accumulating on the furnace breast. The SwingDoor™ has a flexible design which can fit with scrap based as well as DRI based furnaces.

Fig.4 - PTI SwingDoor™: Inside concept view.

Depending on the percentage of scrap charged to the furnace, the SwingDoor™ can be equipped with an integrated burner that operates through the door in conjunction with the other sidewall burners. The door burner melts scrap in the door area eliminating the boiling effect from the cold refractory area in front of the door before it is opened for temperature sampling. In scrap-based furnaces, a burner is mounted onto the SwingDoor™.

The SwingDoor™ designed for 100% DRI based furnaces, with a low percentage of charged scrap, is not implying a slag door burner (flat bath operations).

DESIGN ASPECTS

The main design change needed to the slag door area of the EAF to install the SwingDoor™ solution is the elimination of the slag door tunnel. To accomplish the removal of the tunnel, the slag door is repositioned in-line with the other water-cooled panels of the upper shell.

The refractory around the slag door area is modified to ensure that slag moves smoothly from the furnace into the slag pit or slag pot. Even though the slag door is repositioned dramatically, the existing upper and lower shell designs are kept virtually intact. For the upper shell, a specially designed frame is welded to the structure that allows the SwingDoor™ to attach to the EAF upper shell.

The compact design of the SwingDoor™ ensures smooth operation of existing manipulators and robots (e.g. for automatic temperature and sampling).

The door is designed to have a gap between the tunnel bottom bricks and the door bottom with closed condition. The gap is essential to ensure smooth door movement and avoid door being stuck. The height of the gap depends strongly on the slag composition and differs between scrap-charged and DRI-charged furnaces.

Hydraulics are typically easily adapted from the current furnace hydraulic system. It is recommended that 160 bar are maintained for good operation. PTI has developed a new actuator system that is currently offered for the SwingDoor™ which can be used up to 210 bar.

All components of the SwingDoor™ are engineered to ensure maximum ease of maintenance and operational safety. High-wear parts are secured with pins rather than bolts or welds, enabling fast and straightforward replacement. All utility connections are located at the top of the door, keeping hoses away from heat exposure and other hazards typical of the EAF environment. A complete SwingDoor™ assembly can typically be exchanged with a spare unit within a standard maintenance shift.

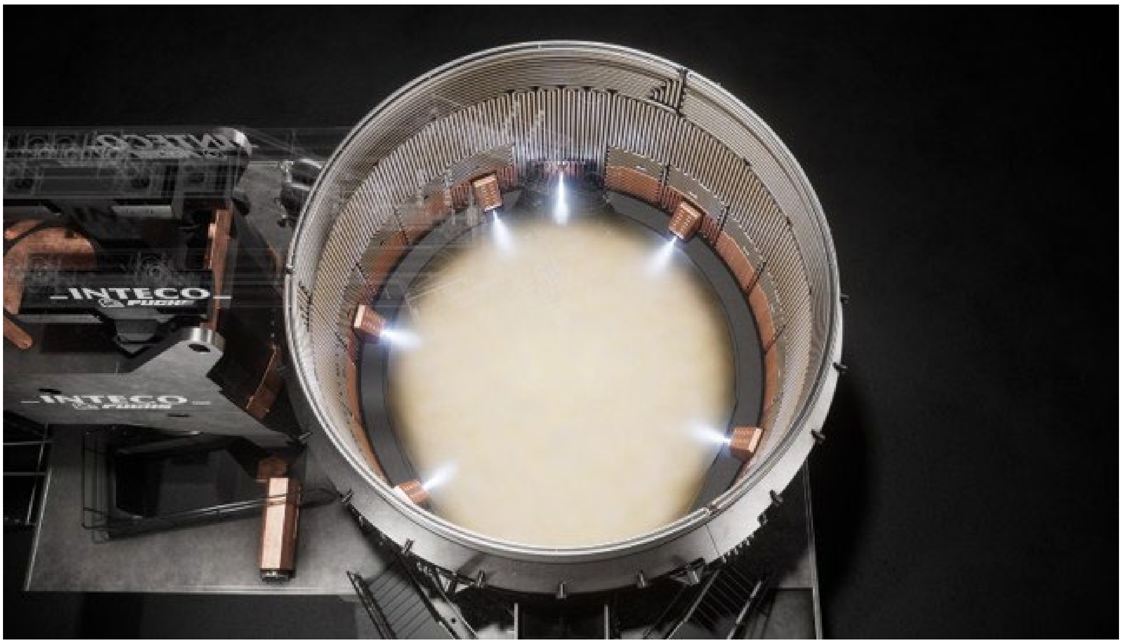

Fig.5 - PTI SwingDoor™ and Chemical Energy Concept view.

INSTALLATION AT C.M.E.

Fig.6 - PTI SwingDoor™ outside view C.M.E.

Fig.7 - PTI SwingDoor™ in operation.

COMMISSIONING CHALLENGES

In this chapter the challenges faced during the commissioning of the SwingDoor™ followed by the measures that solved the challenges are described.

Door closure performance

Unlike ideal installations, structural constraints of the existing furnace at C.M.E. limited upper shell modification and required the door **installed offset from shell panel** line which promoted slag and scrap accumulation at the door interface, potentially affecting closure performance.

"IDEAL" reference installation **C.M.E. installation**

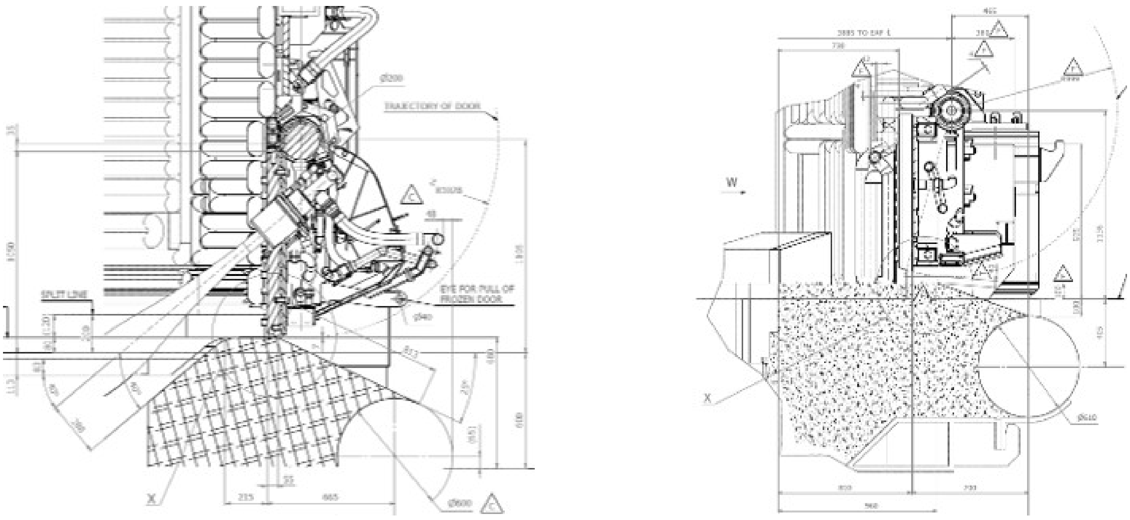

Fig.8 - Comparison "IDEAL" vs. C.M.E. SwingDoor™ installation.

To eliminate potential closure performance issues, the entire operation of the SwingDoor™ got fully automated and integrated into the furnace PLC, with all movements described below requiring no operator intervention.

During melting, the door remains closed. After a pre-defined energy input, the door opens for the first de-slagging. The timing of the 1st de-slagging is highly dependent on rate of slag generation inside the EF (DRI/scrap gangue content).

The first de-slagging is at a power consumption of approx. 35-38 MWh, and the last opening at a power consumption of approx. 46-48 MWh just before tapping for sampling and temperature measurements (see figure 9).

In conventional scrap-based furnaces, this intermediate de-slagging is generally unnecessary due to the lower slag volume. In the C.M.E. process, however, it is required to prevent foaming slag from escaping through the EBT panel opening.

Operator stops feeding lime and DRI when the door is open to further improve material yield and reduce losses through slag.

Shortly before tapping, the door is opened again for the final de-slagging operation. This multi-stage de-slagging improves slag residence time and flux utilization.

During tapping, the door remains closed and is opened to approximately 40° shortly before the rapid back-tilting movement in order to ensure that no steel from the hot heel comes into contact with the door plate.

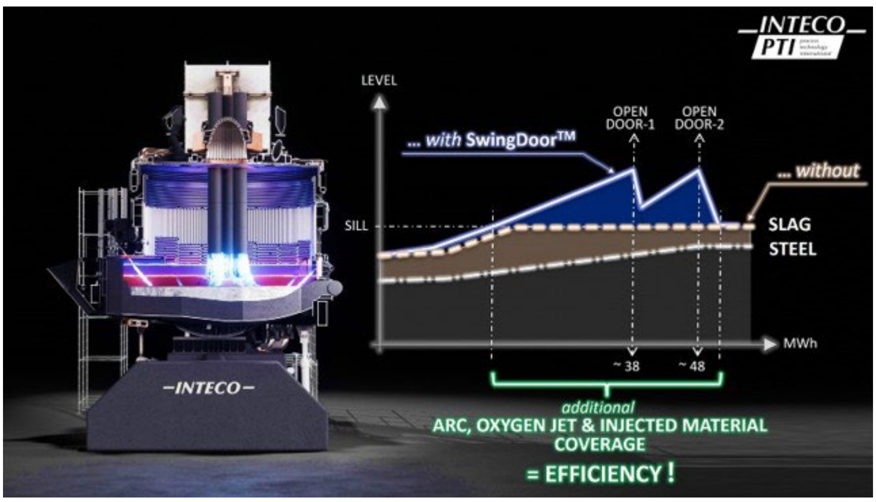

Fig.9 - Advantage of higher foaming slag level at C.M.E.

After tapping, the SwingDoor™ is opened to about a 120° angle to allow the operators to inspect the furnace refractory and, if needed, clean residual slag from the door area and prepare for the next heat.
During charging, the SwingDoor™ is closed to -8° angle to avoid slag accumulation in front of the door and in the tunnel during scrap charging.
An automatic movement to -8° and back to 0° is also integrated to ensure that any slag accumulated directly in front of the door is loosened and removed during the subsequent de-slagging cycle.

Slag chemistry

Operational experience confirmed that slag chemistry significantly influences door sealing performance.
If the slag is too liquid and the level of slag inside the furnace becomes too high, leakages between the lower edge of the door and the breast could occur.
In early operation, supplementary magnesia clinker addition was required at the breast to enhance sealing until slag chemistry stabilization was achieved.
C.M.E. adjusted a higher slag basicity (approx. 1.7 – 1.8) which led to following improvements:

- slag cohesion;
- sealing integrity;
- leakage resistance.

Fig.7 - Comparison Liquid vs. C.M.E. slag.

	Al_2O_3	CaO	MgO	SiO_2	Fe_2O_3	B1	B2	B3
Very liquid slag	8	25	7	20	40	1.25	1.14	0.89
C.M.E. slag	5.04	29.81	13.45	20.90	27.88	1.43	1.67	1.15

Door opening angle measurement

A linear transducer inside the hydraulic actuator was developed during the C.M.E. project (impeded inside the cylinder hydraulic oil) to measure the door opening angle. Initial design placed the linear transducer inside the hydraulic cylinder (cooled down by hydraulic oil) which showed frequent failures due to elevated hydraulic oil temperature.
The radiant heat from slag door zone was the main reason for the elevated temperature of the stagnant hydraulic oil leading to damage the linear transducer.
This configuration proved unsuitable for high-DRI slag operations.
During the 2nd trial, the transducer was relocated and externally mounted on the cylinder body as well as thermally isolated from the hydraulic oil.

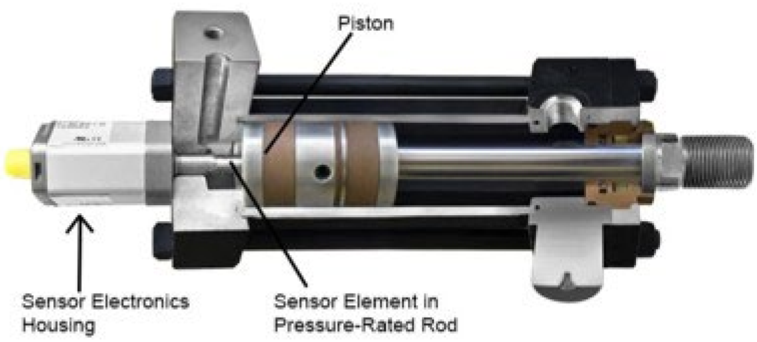

Fig.10 - External Linear Transducer.

Door plate leakage

During the initial trials, C.M.E. observed a water leakage in the lower part of the door plate due to inefficient water cooling for this part.

The circuit was successfully modified during the 2nd trial, and water leakage has been eliminated by:

- optimized inlet distribution;
- improved hose routing.

Thus, leakage frequency was reduced to negligible levels.

MAINTENANCE

The most difficult issue at start-up was the learning curve of how to maintain the breast. The door provided effective sealing performance; however, due to C.M.E. specific door installation not in-line with the water-cooled panel and the long, straight breast area allowing slag accumulation, complete closure was not achieved during initial operation, as the door was obstructed by frozen slag. Frequent cleaning of the door area was required to ensure complete closure of the door. Since cleaning of the breast area was performed using a forklift and the refractory bricks were not mechanically locked, individual bricks became loosened during these operations.

Following the implementation of automatic door operation, including several fully automated short movement cycles while the door remained in the closed and sealed position, the cleaning requirement of the breast area was significantly reduced to approximately one cleaning operation per day.

During a campaign cycle the SwingDoor™ does not require much maintenance. Typically, the work during the down day for preventive maintenance consists of greasing the shaft bushings and roto unions, leak inspection on water connections and hydraulic fittings, checking the bolts on the actuator for torque, and inspecting the clamps on the gas and oxygen piping to the burner. No other maintenance is performed on down days. A campaign at C.M.E. lasts approx. 4-5 weeks. Afterwards the whole furnace (upper and lower shell) is exchanged for refractory repair.

RESULTS

After implementing standardized operating procedures consistently across all crews, C.M.E. achieved significant and measurable performance improvements. Notable gains were realized in yield optimization, reduced specific power consumption (kWh/t), lower slag generation, and decreased electrode consumption.

The realized gains exceeded the original projections and were significantly higher than previously calculated:

- electrical energy reduction > 6,5 kWh/t;
- electrode consumption reduction > 0,025 kg/t;
- metallic yield increase > 0,8 %;
- flux consumption reduction > 1,4 kg/t;
- slag generation reduction > 10 kg/t.

The alignment of operational practices not only enhanced process stability and efficiency but also delivered substantial cost savings. As a result, the financial return on the project was realized rapidly, with a payback period of less than 12 months.

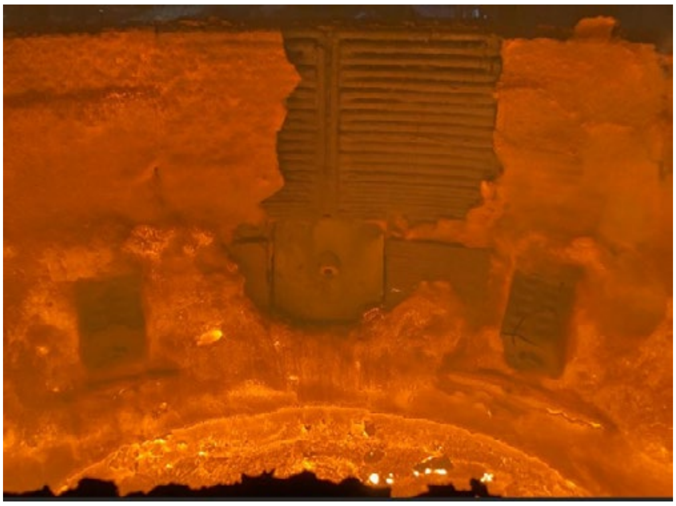

Fig.11 - PTI SwingDoor™ Inside EAF view.

FUTURE ENHANCEMENTS

Operational learnings identified two primary technology enhancement opportunities: the current system operation relies on energy input estimation rather than real-time slag height measurement; future development may incorporate:

- electrical arc signal harmonics;
- acoustic monitoring;
- off-gas analysis;
- thermal imaging.

This would enable predictive de-slagging automation.

Cold slag accretion removal capability may be improved through:

- increased hydraulic pushing force by installation of a hydraulic power pack with higher hydraulic pressure;
- SwingDoor™, including its hydraulic actuator, is designed for hydraulic pressure up to 210 bar. Actually, it is used with only approx. (120 bar).

These enhancements would improve closure reliability in high-slag DRI operations.

SUMMARY

The INTECO PTI SwingDoor™ system has improved the operation of the EAF's at C.M.E. facility by eliminating the slag door area as a cold spot, controlling the removal of slag. The design of the SwingDoor™ allows the slag door area to remain closed during the melting and refining stages of the heat. While the SwingDoor™ was designed to retain more of the slag in the EAF, operators at the same time gained more control over when slag leaves the furnace and the amount of slag that leaves the furnace.

In addition, a significant reduction in FeO, energy, electrode and lime consumption was experienced.

ACKNOWLEDGEMENT

Special thanks to the melt shop and maintenance management teams in C.M.E. for their support and trust in this technology, their diligence in design, attention to detail and for their input in practice development that helped make these installations successful.

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