EAF Application of SmartFurnace and ZoloSCAN Laser Off Gas Measurement Technology at Vallourec Star

2015

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Keywords: Electric Arc Furnace, Off Gas Analyzer, Optimization, Water Leak

ABSTRACT

This paper describes the implementation and preliminary results of the ZoloScan Laser Off Gas Measurement and its integration into the EAF SmartFurnace System at Vallourec Star, Youngstown-OH operations. The main objectives of this development are the improvement of safety conditions through better detection of potential water leaks in the furnace and the reduction of operating cost through process optimization.

In late 2015 the ZoloSCAN TDLAS Off Gas Analyzer was installed providing reliable and near real time measurement of CO%, CO2%, H2O% content and temperature of the off gas. The measurement is performed by a laser positioned at the exit of the furnace off gas duct. The information is integrated into the SmartFurnace System, which was installed in 2012, through the Off Gas Control module and used for dynamic control of the chemical energy inputs. Key process variables such as carbon injection, oxygen and natural gas flow were automated using the data from the system. The water content in the off gas is also measured and the data is used to generate alarms to the EAF operators for potential water leaks in the vessel, improving safety to personnel and equipment.

INTRODUCTION

About Vallourec Star

Vallourec Star is a leading producer of premium seamless pipes (Oil Country Tubular Goods – OCTG) used primarily in oil and gas applications. Vallourec Star offers the latest technology in steel making and pipe mill production, heat treatment and threading facilities and customized specialty service products. With operations in Muskogee, Oklahoma; Youngstown, Ohio; and Houston, Texas, and sister companies in Canada and Mexico, Vallourec facilities are ideally positioned to serve North America oil and natural gas markets. Vallourec Star is a joint venture between Vallourec and Sumitomo Corporation. Vallourec is a world leader in premium tubular solutions for the energy markets and for demanding industrial applications operating in more than 20 countries.

SmartFurnace System Description

The SmartFurnace System is an integrated system which is designed to control all the furnace consumables as well as the electric power input. The system is divided in three main modules: SmartArc (Electrical Power Input Control), the Chemical Energy Control Module and the Off Gas Control Module. Each sub-system or module optimizes the operation of the equipment it controls not only following a number of autonomous rules but also receiving continuous feedback from other control modules. For example, if a power input profile is designed to produce a faster heat, the Chemical Energy Control Module will change the operation of the burners in order to arrive with the correct carbon at the end of the heat.

The Off Gas Control Module will analyze the information provided by the ZoloSCAN TDLAS Off Gas Analyzer, compensate the Chemical Energy Control to have a higher efficiency and alarm for any abnormal water situation. This system is designed to optimize each part of the process with minimal changes required when developing new practices. It also compensates for variations in the process.

SmartARC

The central concept behind the power profile is to provide the capability to start with a very simple program and then add more flexibility and functionality as needed. Several features in the system allow it to modify its operation in order to cope with process variations. The new stability meter provides help identifying the heat stages and slag conditions during the heat. The SmartArc system takes full advantage of this measurement. Some of the most important features are described next.

Chemical Energy Control Module

The Chemical Energy Control Module is designed to provide a robust control system capable of handling different furnace conditions, scrap mixes, practice changes, etc. The main difference from a conventional burner program (based only on energy steps) is that the control module has several sub-modules with specific functions to determine the different requirements for process optimization. The system simultaneously predicts temperature of the steel and the carbon content based on consumables information. In turn, it controls the carbon content and slag foaming in order to achieve optimal results.

Off Gas Control Module

The Off Gas Control Module design has two main goals: Optimize the chemical energy into the EAF and detect abnormal water vapor events inside the EAF. The Off Gas Control Module estimates with algorithms the percentage of CO generated by all sources of carbon into the EAF such as DRI and carbon injectors. The module closes the control loop with the real value provided by the Zolo TDLAS Off Gas Analyzer. The Off Gas Module will increase or decrease the carbon injection and oxygen to reduce the emissions of CO and increment the percentage of CO2 produced during the combustion of carbon and oxygen optimizing the chemical inputs in the EAF.

The Off Gas Control Module estimates with algorithms the levels of water vapor during all stages of the heat. The Off Gas Control Module compares the estimated water vapor with the real time water vapor sent by the Zolo TDLAS Off Gas Analyzer and determines if there is an abnormal quantity of water vapor inside the EAF. Figure 1 represents all control modules available in the SmartFurnace:

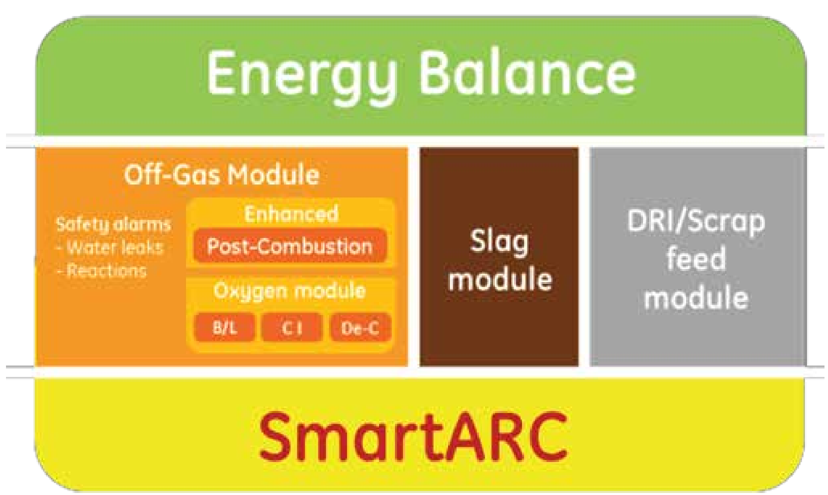

Figure 1. SmartFurnace Control Modules

Zolo TDLAS Off Gas Analyzer Description

ZoloSCAN is unique as a Tunable Diode Laser Absorption Spectroscopy (TDLAS) technology due to its proprietary multiplexing technology. Multiplexing enables many lasers to be combined onto one single light beam (or light path). The single multiplexed light path is pitched across the combustion space via a SensAlign Head. A second SensAlign Head is used as a catch head to receive the light and send it back to the control rack for de-multiplexing and signal processing1.

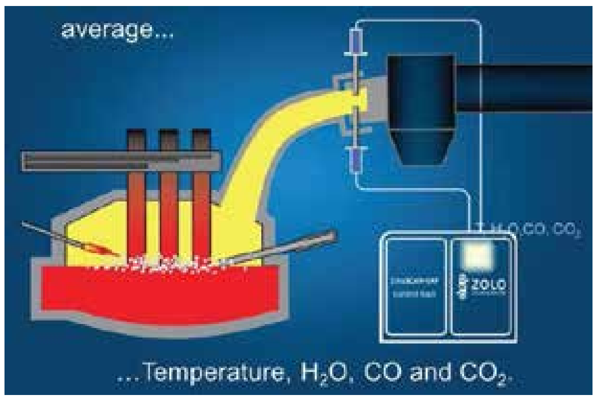

Figure 2. ZoloSCAN TDLAS Off Gas Analyzer System Overview

The Zolo TDLAS Off Gas Analyzer provides real-time, in-situ, simultaneous measurement of temperature, CO, CO2 and H2O at an agreed location near the 4th hole gap as shown in Figure 3. The ZoloSCAN-EAF system is the only real-time combustion sensor that can obtain key combustion constituent measurements in the ultra-harsh combustion environment of the EAF duct in less than 2 seconds. It has low maintenance requirements and does not need periodic calibration. Each SensAlign head has an automatic alignment capability to maximize the laser power strength through all the heat stages. This reduces measurement losses during periods of instability. Figure 4 is an example of a representative heat of ZoloScan reading.

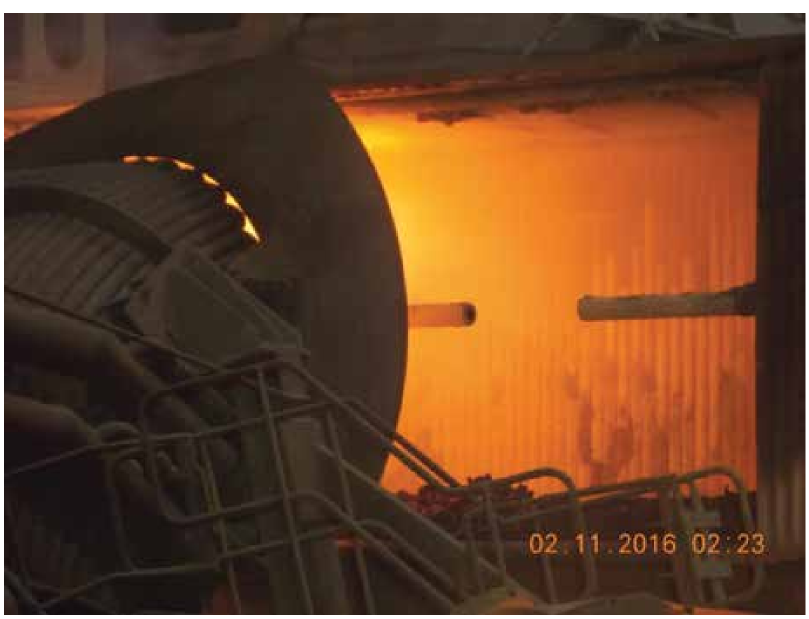

Figure 3. Zolo probes installation at Vallourec Star

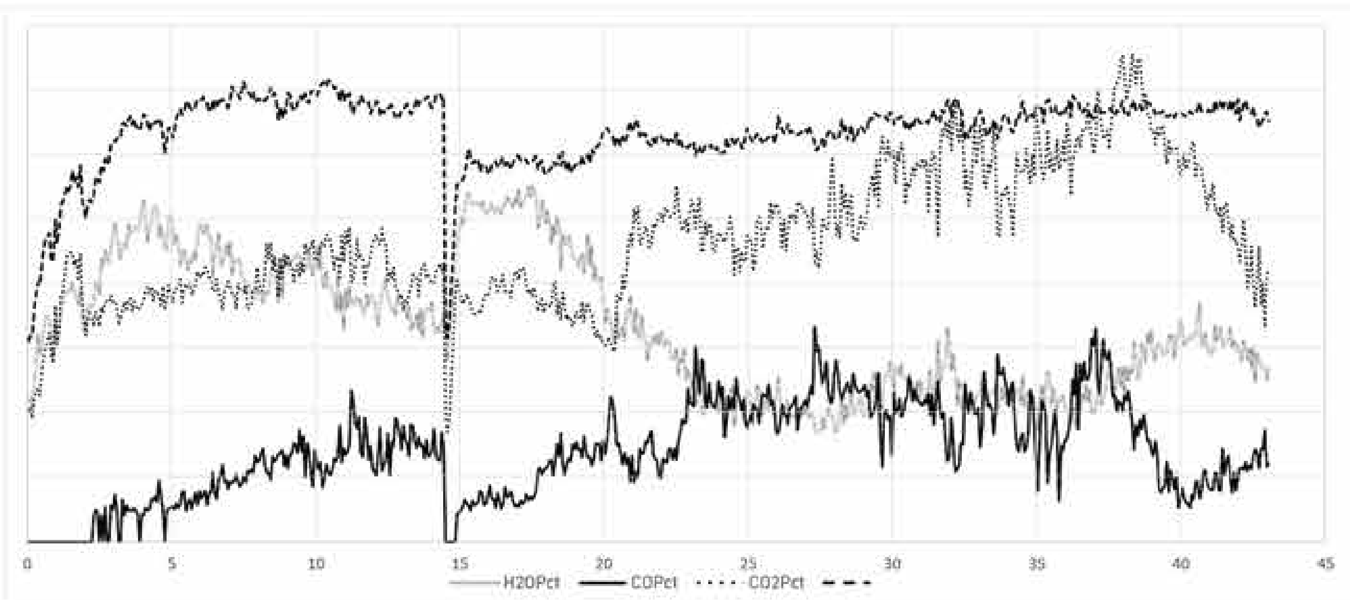

Figure 4. Typical Off Gas Measurement by ZoloSCAN

Furnace Description

The electric arc furnace at Vallourec Star is a 20-foot diameter Fuchs AC-EBT, 100 tap ton capacity with an average 25 ton hot heel. The capacity of the transformer is 78.4 MVA with an online reactor of 5.1 ohms. The maximum voltage and currents are 1100 V and 59.25 KA respectively. The furnace is equipped with 4 PTI burners. Three of the burners are enabled with super-sonic oxygen injection and two have carbon injection capability. Maximum O2 flow capacity is 1250 scfm and 250 scfm of natural gas per burner.

Figure 5 shows the position of the burners and the 5th hole roof feeding port. Steel temperature, oxygen and chemistry samples are obtained by an automated mechanism installed on the furnace side wall next to the slag door.

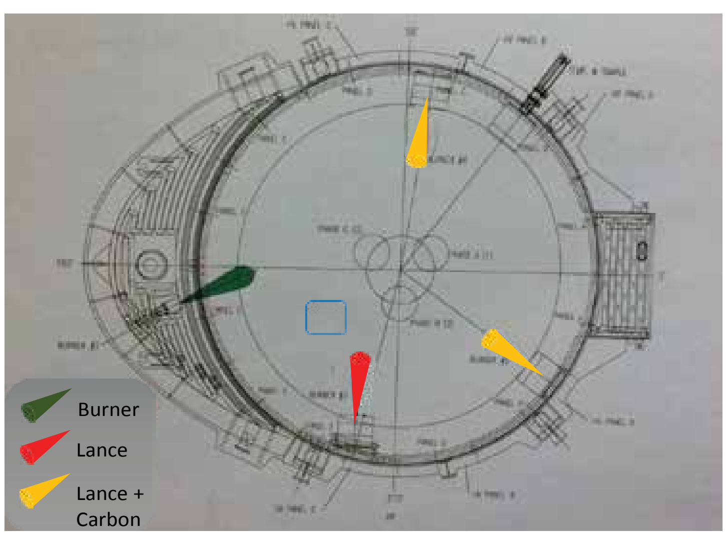

Figure 5. EAF layout diagram

DEVELOPMENT

Chemical Energy Dynamic Control through Off Gas Analyser

The Off Gas Module, which is part of the SmartFurnace optimization system, uses ZoloSCAN Analyser data in order to dynamically control carbon injection, natural gas and oxygen flows. The CO/CO2 ratio, energy consumption, arc stability and estimated steel bath oxidation are used by the Off Gas Control Module to modify carbon injection during refining. Figure 6 shows the order used by the algorithm to calculate the final set points to be used for the duration of a scan. Carbon references are subjected primarily to the stability of the bath and its estimated oxidation. A subsequent compensation is carried out by the Off Gas Control Module, taking into account instant and average heat CO/CO2 ratios, a variable CO/CO2 ratio target and a previous validation of the off gas data. This makes it possible to significantly reduce injected carbon consumption while ensuring good bath stability and bath chemistry. The natural gas and oxygen flow ratio is adjusted during melting in order to promote complete combustion.

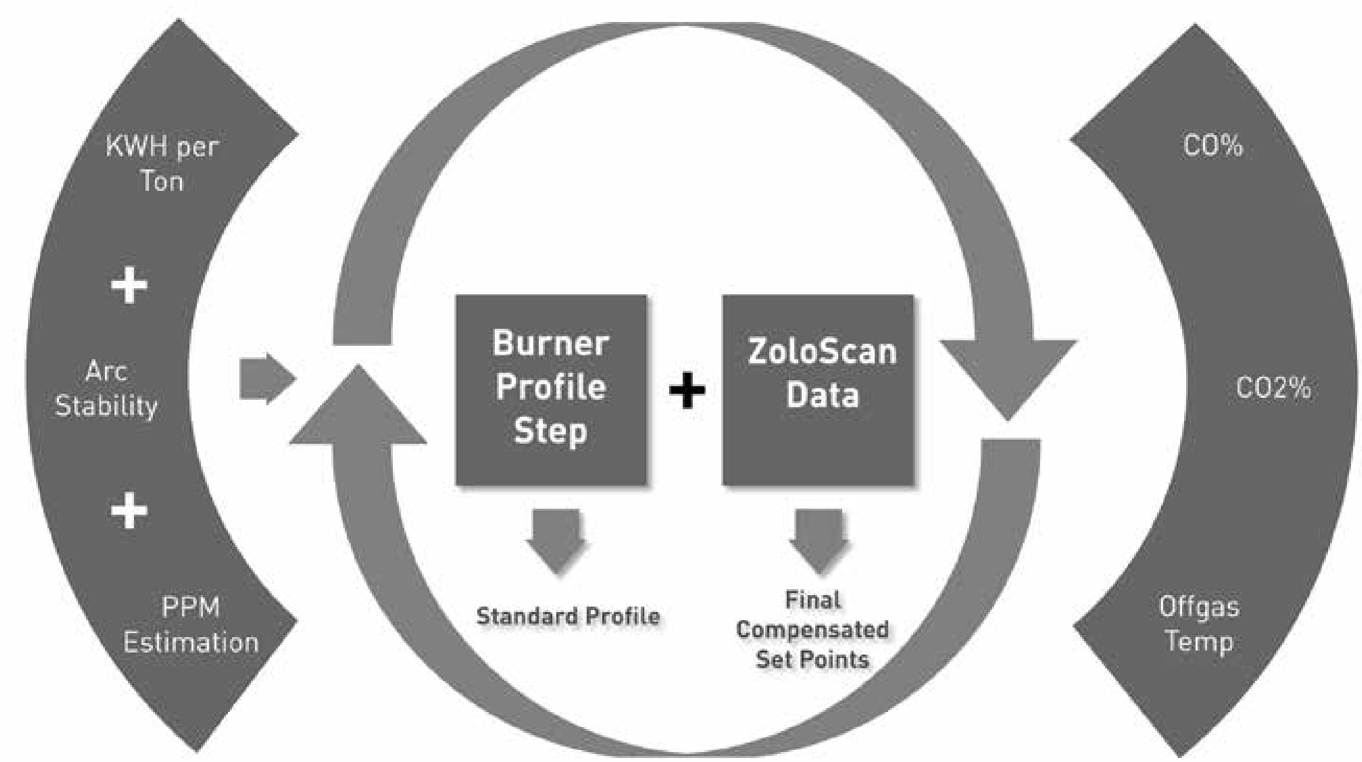

Figure 6. Dynamic compensation of carbon and oxygen references by Off Gas measurement.

Figure 7 shows a typical correlation between measured CO% and carbon injection flow. As a result, carbon injection can be modified in order to obtain a target CO profile. CO profiles may vary depending on the carbon percentage in the scrap mix, and finding an optimum CO target becomes crucial in order to maintain good stability, iron recovery and low refractory wear rates. As mentioned before, oxygen concentration is also modified with the purpose of increasing post-combustion inside the furnace.

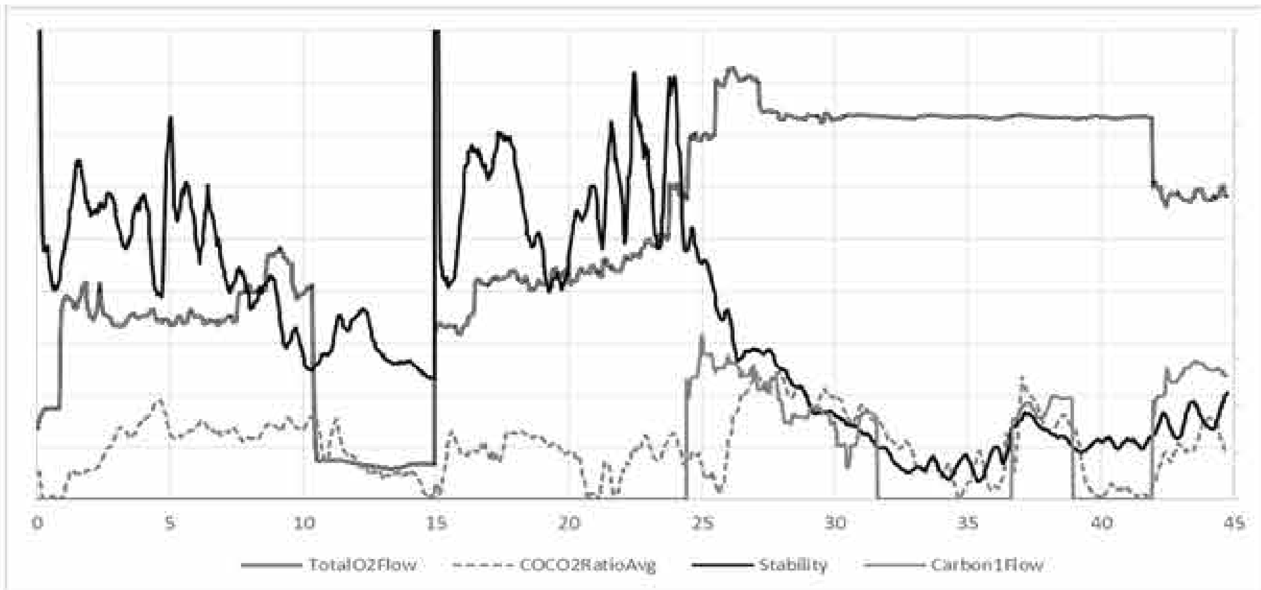

Figure 7. Carbon Injection Flow vs CO% variation during the heat.

Slag foaming is essential to cover the arc and improve energy transfer efficiency. For this reason, CO formation is necessary to promote slag foaming and ensure good stability in the bath. However, a significant portion of the input energy is lost in the off gas as sensible and chemical energy. It can observed in Figure 7 that stability is positively affected by the change on the carbon practice. Figure 8 shows a comparison of the stability level during refining before and after implementation of the Off Gas Control Module. Lower stability equates to less variation in the current and more uniform melting of the heat. This directly relates to decreased power on times and consequently improved electrode and electric energy consumptions.

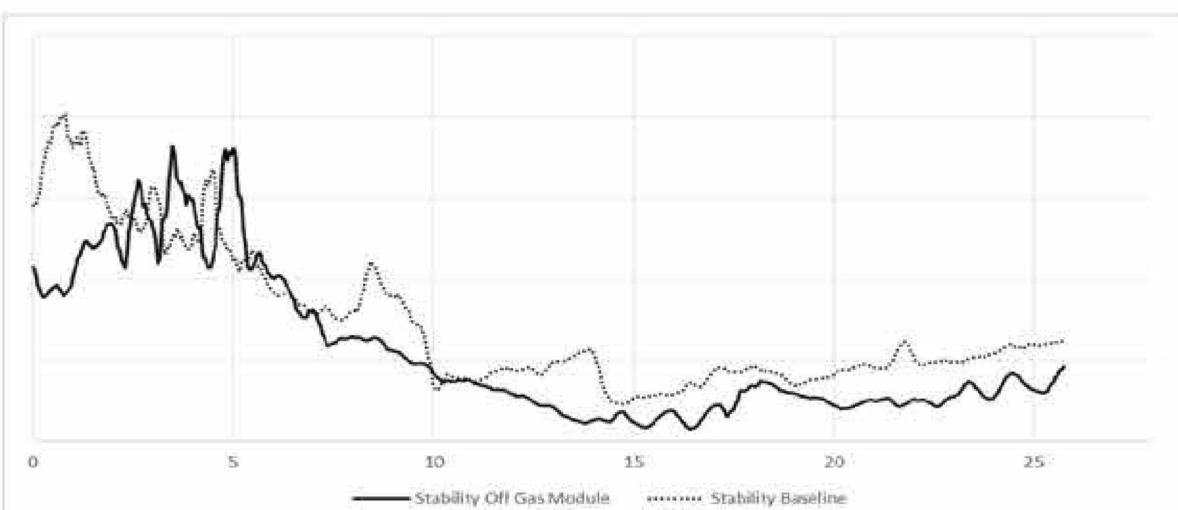

Figure 8. Stability in the bath during refining, a typical heat before and after Off Gas Control Module Implementation. A lower stability value indicates a more stable bath.

Detection of Abnormal Water Vapor

The goal of the Abnormal Water Vapor (AWV) Module is to warn the operators whenever excess water is detected, especially to avoid explosions or risky situations. Due to potential high safety risks, this system needs to be reliable, sensitive and fast as demonstrated at the Vallourec Star installation.

The ZoloSCAN analyzer H2O% measurement scan rate is less than 2 seconds and the measurement availability was over 98% in more than 1 year of operation. The sensitivity of the measured H2O% has been demonstrated by the difference in water vapor corresponding to electrode water spray adjustments. As a simple example, there is a significant difference between measured %H2O with the electrode sprays off compared to the sprays on at normal set points as shown in Figure 9.

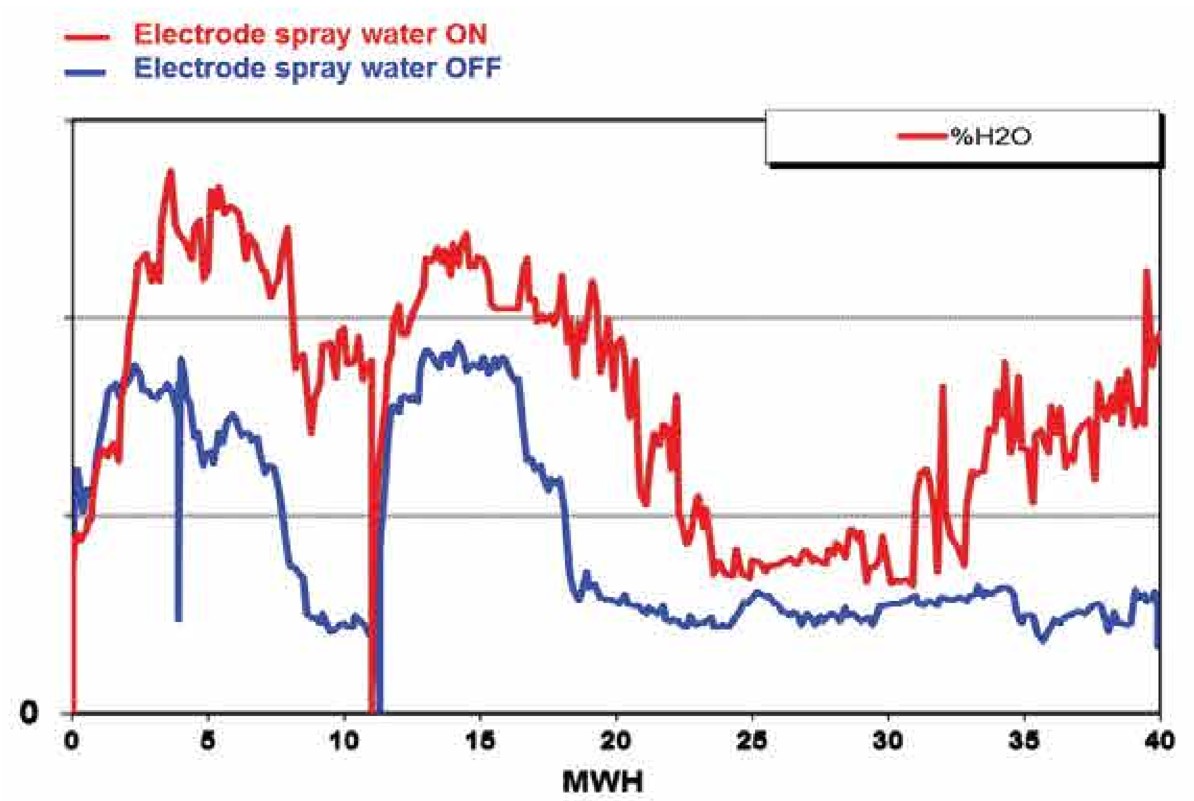

Figure 9. Electrode flow on/off test

In order to generate AWV alarms, this module calculates the expected amount of water vapor inside the furnace and compares it against the Zolo off gas analyzer measured H2O%. Using a custom based logic, the AWV module generates a warning or an alarm with its severity level to the furnace operators via HMI communication. The water vapor estimation is based on a multivariable non- linear model, which takes into account several process related variables such as off gas flow, used energy, off gas temperature, furnace stability, electrode cooling flow, tilt angle, air intake, etc.

In addition, a camera has been installed in order to detect furnace pressure changes that affect the off gas flow. The target for this instrument is to measure flame intensity near the roof and delta. This signal helps to estimate changes on pressure and to adjust the estimate of steam output to prevent false alarms.

Figure 10 shows the AWV model estimated water vapor percentage and the ZoloSCAN measured H2O% on a typical two charge heat with normal water vapor throughout the heat. The measured H2O% (dotted line) and the estimated H2O% (solid line) follow each other closely.

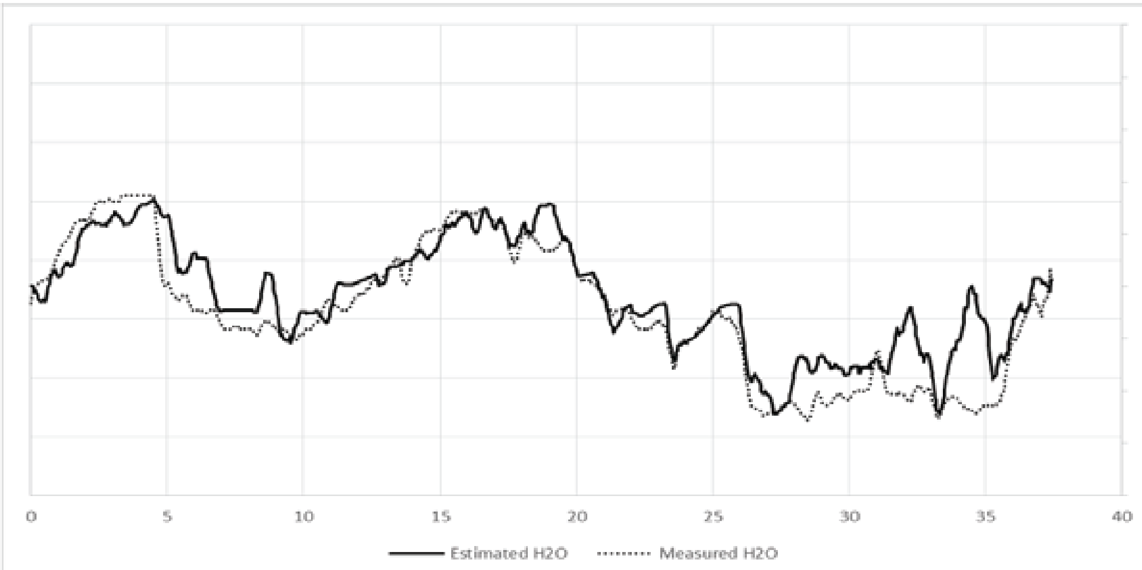

Figure 10. Estimated vs. measured water vapor on a typical heat

Figure 11 shows an example of a real water leak that was detected. After 20 minutes into the heat, the measured H2O% is much greater than the estimated H2O%. A positive difference between the two accumulates in an alarm integration value (AWV Accum), which will result in an alarm being sent if the integration value exceeds a defined threshold. On this heat the alarm was activated and the operators reported a medium roof panel leak, which was repaired after tapping.

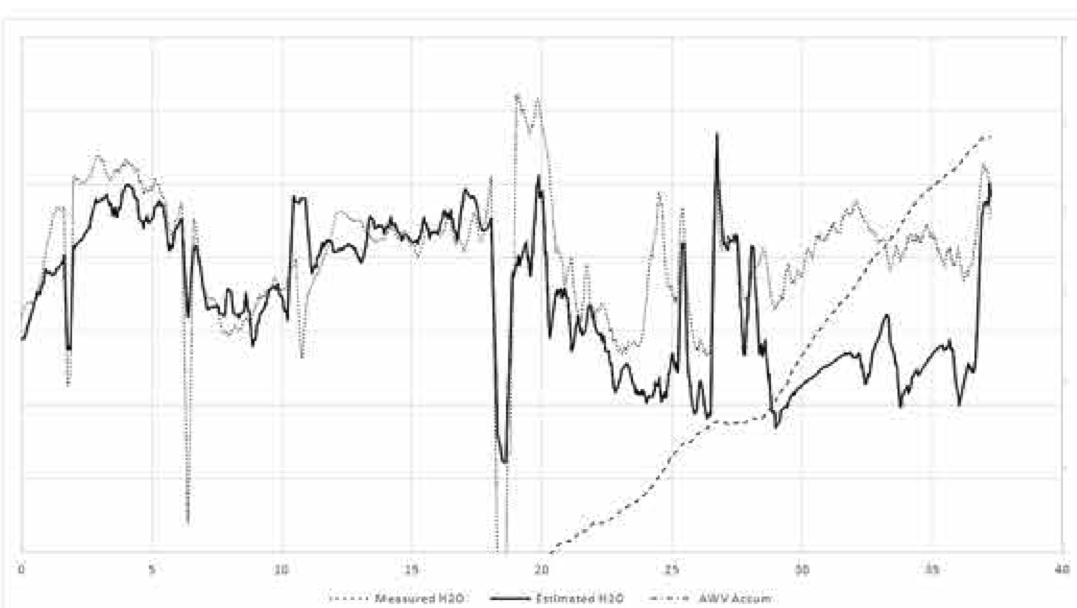

Figure 11. Estimated vs. measured water vapor with a medium panel leak

In addition to typical electrode spray testing, the sensitivity of the measurement has been confirmed by an increase of observed water vapor detected after applying a slurry of powdered refractory with 10-15 weight % water content in the form of gunning repairs to the EAF refractory lining. On these heats extra vapor is integrated during the first minutes of the heat as seen in Figure 12, compared to a nominal heat with no gunning event and no accumulated abnormal water vapor as shown previously in Figure 10.

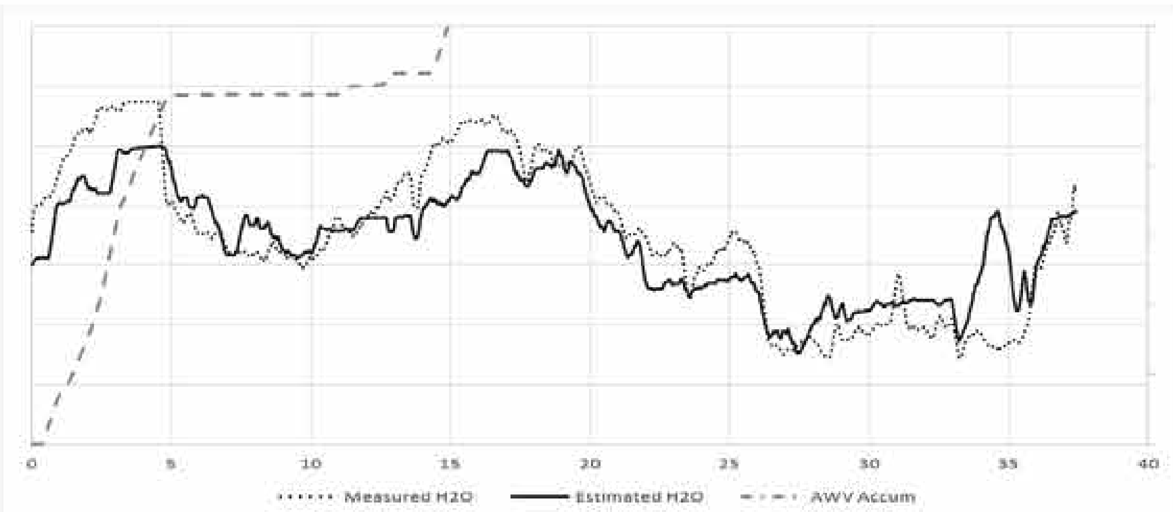

Figure 12. Estimated vs. measured water vapor after a gunning event.

RESULTS AND DISCUSSION

Table 1 provides the results of the optimization process under one crew operation regime. A 100% scrap grade and a 30% pig iron grade were considered for the economic analysis. These two grades represent about 75% of current and historical Vallourec Star production.

The EAF performance has been evaluated by analyzing the main operation EAF process indicators such as energy consumption, electrode consumption, productivity, additions made to the heats, etc. Only indicators that were statistically different (better/worse) are presented. In addition, critical EAF process variables have also been analyzed, e.g. steel temperature at tap, level of steel oxidation at tap, %FeO in slag and the slag foaming quality during refining.

	%Change	
	100% Scrap Summary	Pig Iron Grade Summary
Natural Gas	-3%	0%
Charge Carbon	4%	N/A
Foamy Carbon	-11%	0%
EAF Electrode	-11%	-11%
Aluminum	0%	-7%
EAF Electricity	-3%	-5%
Total Oxygen	2%	2%
Dissolved Oxygen at Tap	0%	-19%
Tap Temperature	17°F higher	12°F higher
FeO in Slag	0%	-4%
Average Slag Stability	-20%	-5%
Power on Time	-5%	-6%

Table 1. Results under 1 crew operation.

CONCLUSIONS

Safety is a primary concern in steelmaking operations and a core value for Vallourec Star. The implementation of a reliable real-time abnormal water vapor detection system can significantly reduce water related safety risks in the EAF. The Abnormal Water Vapor module in conjunction with ZoloSCAN system is capable of warning operations of a possible water leak inside the furnace.

In addition, furnace process improvement has been achieved by integrating the ZoloSCAN data into the SmartFurnace optimization system, significantly reducing operating costs.

REFERENCES

1 .K. Grieshaber, F. Martinez, "ZoloSCAN Laser Diagnostic System for EAF Leak Detection and Process Optimization", METEC & 2nd ESTAD Conference 2015.