UTILIZING TENOVA GOODFELLOW'S EFSOP® TECHNOLOGY TO IMPROVE EAF PERFORMANCE AND ENHANCE SAFETY[1]

Nadia Boin[2]
Armando Vazquez[3]

Abstract

Tenova's Goodfellow EFSOP® system was commissioned at Ferriera Valsabbia's 90 ton EAF to improve the furnace performance and to increase safety via the EFSOP® water detection technology. Optimization of the process through off-gas measurements provided by the EFSOP® system was applied: 1). To obtain greater efficiency of the chemical package and its application during the melting process while improving the consistency and composition of the slag based on efficiency of the Carbon Injection 2) To control the fume system 4th - hole damper diminish transfer of energy towards the bag house and better control of the air flow. The EFSOP® water detection software provided alerts that were able to indicate abnormal water events in the furnace. The alerts were tuned to minimize the rate of false alarms while maximizing the probability of alerting for abnormal water conditions. Water was injected into the furnace for verification and analysis using the real-time water leak data. The EFSOP® system reduced furnace operation costs but more importantly improved safety. This paper will provide a summary on how the EFSOP® technology was used to optimize the furnace including details on the use of the off-gas measurements with the EFSOP® Water Detection software.

Keywords: Optimization; EAF; Steelmaking; Off-gas; Post-combustion.

UTILIZANDO A TECNOLOGIA EFSOP® DA TENOVA GOODFELLOW PARA MELHORAR O DESEMPENHO DO FEA E APRIMORAR A SEGURANÇA

Resumo

O sistema EFSOP® da Tenova Goodfellow foi comissionado no FEA de 90 t da Ferriera Valsabbia para melhorar o desempenho do forno e para aumentar a segurança com a Tecnologia EFSOP® de Detecção de Água. O sistema EFSOP® permitiu a otimização do processo através de medições dos gases de exaustão: 1) Para obter maior eficiência do pacote químico e sua aplicação durante o processo de fusão e ao mesmo tempo melhorando a consistência e composição da escória baseadas na eficiência da Injeção de Carbono; 2) Para controlar o damper do sistema de despoeiramento do quarto furo diminuindo a transferência de energia para a casa de filtros e melhorando o controle da vazão de ar. A Tecnologia de Detecção de Água EFSOP® forneceu alertas que foram capazes de indicar eventos anormais de água dentro do forno. Os alertas foram ajustados para minimizar a taxa de alarmes falsos e maximizar a probabilidade de alertas em condições anormais de água. Água foi injetada no forno para verificação e análise utilizando os dados de vazamento de água em tempo real. O sistema EFSOP® reduziu os custos de operação do forno mas, mais importante, melhorou a segurança. Este trabalho apresenta um resumo de como a tecnologia EFSOP® foi utilizada para otimizar o forno incluindo detalhes do uso das medições dos gases de exaustão com a Tecnologia de Detecção de Água EFSOP®.

Palavras-chave: Otimização; Aciaria elétrica; Gases de exaustão; Pós-combustão; Detecção de água.

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[1] *Technical contribution to the 42nd Steelmaking Seminar, May, 15th-18th, 2011, Salvador, BA, Brazil.*

[2] *Process Engineering, Tenova Goodfellow Inc., Mississauga, Ontario, Canada*

[3] *Sales & Marketing, Tenova Goodfellow Inc.*

1 INTRODUCTION

1.1 Plant

Ferriera Valsabbia SpA. was founded in 1954 and produces rebar, wire mesh and billets. The average annual productivity of the plant of 112.5 t/h. Equipment details on the Ferriera Valsabbia SpA. plant are listed below in Table 1.

Table 1: Electric arc furnace details at Ferriera Valsabbia

Furnace Diameter	5.2 m
Furnace Capacity	80 tons tapped
Annual Production	850.000
Transformer	80 MVA
Burners (custom build)	4 couples of burners
Post Combustors	2+4
Oxygen Injectors	4 supersonic injectors
Carbon Injectors	2 injection points

Tenova Goodfellow's EFSOP® system was commissioned at Ferriera Valsabbia (BS) Italy in October 2007 to improve the performance of 80 ton EAF and to increase safety via the EFSOP® water detection algorithm by detecting the presence of water in the EAF that is not considered a normal part of the furnace operation (i.e. abnormal water events).

The EFSOP Water Detection Technology™ was tested via controlled water injection trials through the slag door and increased electrode spray water trials. The Technology was able to distinguish charges with water injection from those without. As a result of the position results from the trials, the system is currently being tuned to understand the false alert rates before being implemented by the plant for on- line, real-time abnormal water event detection.

1.2 EFSOP® System and Closed Loop Control (CLC)

The EFSOP® system measures and analyzes the off-gas composition (CO, CO_2, H_2, and O_2) at the 4th hole of the EAF in real time and uses this information for closed loop control (CLC) process optimization. Additionally, off-gas analysis provides useful information to operators and production personnel to help better understand the EAF operation and to reduce overall conversion costs.

Figure 1 illustrates the three main components to the EFSOP® system and how they are integrated into the control of the furnace. The main components in the EFSOP® system are:

1. Patented EFSOP® probe,
2. EFSOP® HMI and SCADA computer and,
3. EFSOP® Gas Analyzer

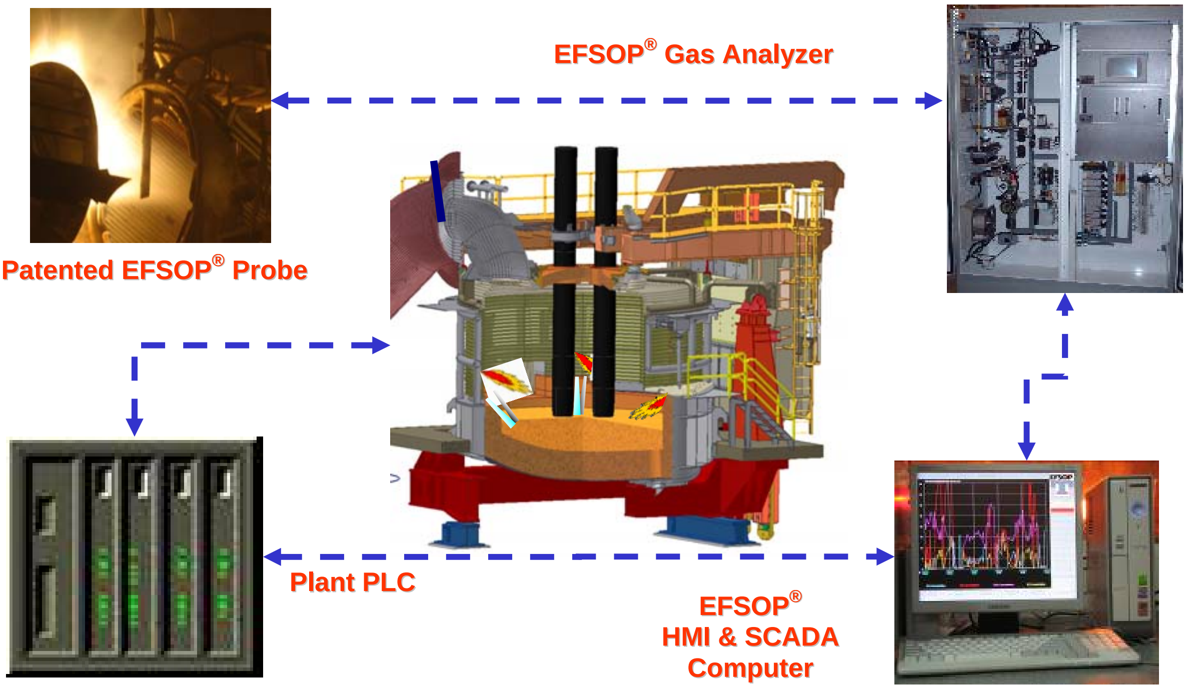


Figure 1. Schematic of the EFSOP® system components.

The patented water cooled sample probe continuously extracts sample gases from the 4th hole of the furnace as illustrated above. The water cooled probe is equipped with an automated purging system designed to purge both the probe and the filter with pressurized nitrogen. The purging cycle, which occurs when charging, helps to ensure the probe is cleaned and is able to sample the furnace gas. The heated sample line transports the furnace off gas to the EFSOP® analyzer where the sample is filtered to remove dust and moisture before being analyzed for concentrations of CO_2, CO, O_2 and H_2.

The off-gas sample is collected from the EFSOP® water cooled off-gas sample probe mounted in the water cooled D1-duct. The sample gasses are drawn under vacuum through the barrel of the probe. The position of the probe is customized to ensure that the sample extracted is true furnace off-gas that has not been dilutedby air entering at the combustion gap.

The extracted off-gas sample is transported through a heated sample line to the analyzer cabinet. Upon reaching the analyzer cabinet the sample is filtered for dust and dried before reaching the multi-gas analyzer. The multi-gas analyzer measures levels of O_2, CO, CO_2 and H_2 and sends the data to the Plant PLC. The EFSOP® SCADA/HMI computer evaluates the analyzer data and determines the optimal set-points for the furnace equipment (Burners, Injectors, Damper position, etc.) for dynamic closed loop control. Additional information about the Tenova Goodfellow EFSOP® system can be found in other technical papers.(1-6)

2 EFSOP® HOLISTIC PROCESS IMPLEMENTATION

2.1 EAF Optimization

The most significant improvement to the process came from the reduction in methane consumption. Burner set-points were tuned with the closed loop control (CLC) system to help reduce methane during periods where the more efficient post combustion of carbon monoxide was occurring. The EFSOP® HMI was used to implement operational programs based on a melting percentage provided by the plant. The EFSOP® HMI provided a convenient platform to make changes to and to track burner profiles that were tested and used. It also allowed Ferriera Valsabbia to create custom operational programs for various differing conditions. For example, programs were implemented and optimized for low production conditions and to target specific productivity for higher demand periods.

Algorithms were implemented to control the 4th hole damper control, which further helped improve the furnace efficiency and reduce operating costs. The control of the 4th-hole damper in response to off-gas composition as determined with EFSOP® technology was based on the calculated percentage of nitrogen in the off-gas. Nitrogen is determined as the balance concentration in the off-gas ($N_2\%$ = 100% - $O_2\%$ - CO% - $CO_2\%$ - $H_2\%$). Nitrogen does not participle in the combustion reaction and can lead to the generation of NO_x if passed under the arc of the electrode. The continuous drafting of air through the furnace robs the furnace of heat and slows the melting process.

The damper control algorithm implemented at Valsabbia has three damper set points based on $N_2\%$ from the EFSOP® system. The three settings work as follows: 1) Setpoint #1: if $N_2\% > X$, 2); Setpoint # 2: if $N_2\% < Y$ and, 3); and Setpoint # 3: if $Y>N_2\%>X$. Overall, this allowed the damper to be open to maximum when large amounts of combustible gases were present in the furnace and to maintain as much heat in the furnace when the combustible gases are at their lowest. The third setpoint allows for a much more dynamic control and smoother transition of damper position based on what is actually in the furnace as opposed to a more traditional static control of the damper.

2.2 Optimization Benefits

Base on the implementation of CLC and the optimization strategies savings in electrical and power on time (POT) were realized. The EFSOP® HMI provides flexibility to implement custom operation programs for various differing conditions.

The optimization strategy applied to control the damper set points gives the opportunity to optimize the continuous drafting of air through the furnace while optimizing the melting process. The dynamic control helps to increase post combustion in the furnace; thereby improving the efficiency of heating and scrap melting; decreasing overall conversion costs; and reducing the heat load on the fume system.

3 EFSOP® Water Detection

3.1 Implementation of the Water Detection Module

The EFSOP Water Detection Technology™ uses the EAF off-gas measurements from the EFSOP® analyzer to determine abnormal water events in the furnace. The methodology first characterizes the normal level of water in the EAF operation such as electrode water spray, moisture contained in the scrap and the by-product from combustion reactions. The characterized normal level of water is compared to the level of water encountered during the active heat to trigger an alert condition. Abnormal water events in the EAF can be created by water panel leaks, seasonal changes resulting in heavy rain or snow contained in charge and changes in scrap that contain higher than normal levels of oils or organic material (turnings, tire wire, etc). The benefits for detecting abnormal water can minimize the risk of furnace and fume system explosions that can lead to equipment damage, injury and loss of life.

The EFSOP Water Detection Technology™ is a statistical method and so there exists a trade-off between the confidence level of abnormal water detection and false alarms. For instance, if the confidence limits for water-detection are set to 100%, the system will alert at all probable water events but with an unacceptable number of false alarms. At a lower confidence limit, the number of false alarms decreases but at the risk of missing probably water events. Tuning requires that the confidence limits are set such that the maximum number of water events are indicated at an acceptable level of false alarms significantly increasing the number of false alarms.

The EFSOP Water Detection Technology^{TM} uses the concentration measurement of hydrogen and the ratio of hydrogen to carbon monoxide in the off-gas as an indication of the level water in the furnace. Water participates in oxidation reactions in the EAF, such as the conversion of carbon monoxide to carbon dioxide and that of iron to iron oxide. These oxidation reactions produce hydrogen resulting in an increase in hydrogen concentration. The oxidation of carbon monoxide by water is indicated by an increase in the ratio of hydrogen to carbon monoxide. The ratio of hydrogen to carbon monoxide will vary throughout the melting and refining periods of any one heat and from one heat to the next. The pattern of this variability is similar over a given time period of heats utilizing the same burner practice and scrap mix. Using statistical off-gas data of historic heats, a general fingerprint of the H_2 and H_2/CO ratio is made for each burner practice broken down by charge and refining periods. The fingerprint profiles of H_2 and H_2/CO ratio determined at Valsabbia are plotted on an energy consumption basis (kWh/charge, MWh/charge ton, melting % etc), as shown in Figure 2.

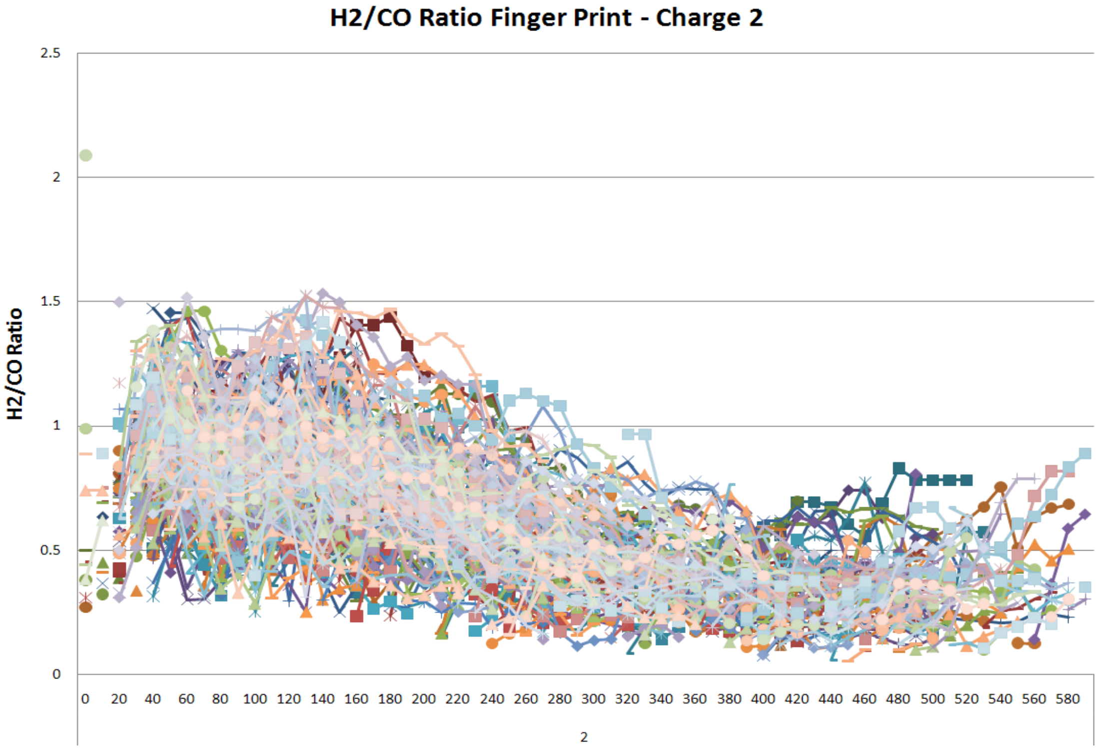


Figure 2. Example of H_2/CO fingerprint for single charge.

The practice is characterized by segmenting the H_2 and H_2/CO ratio into defined timing bins (kwh/charge, MWh/charge ton, etc). The size of the timing bins are defined for a period where the fingerprint trends show a level of relative constancy. The thresholds for each of the alert metrics (H_2 and H_2/CO) are generated for each of the defined bins. Smaller bin sizes increase the sensitivity to alert for abnormal water conditions, but give more false alerts. Whereas larger bin sizes will generalize the fingerprint and thereby reduce the sensitivity to give a reduced rate of false alerts. Figure 3 provides an example of alert threshold bins for detecting abnormal levels of hydrogen. More information and details on fingerprinting of the water detection alerting metrics can be found in other technical papers.(5)

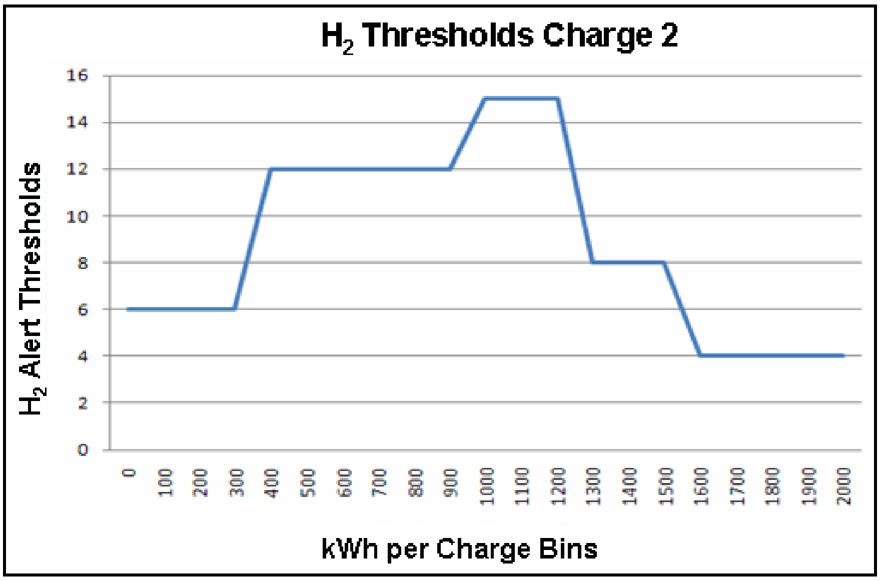
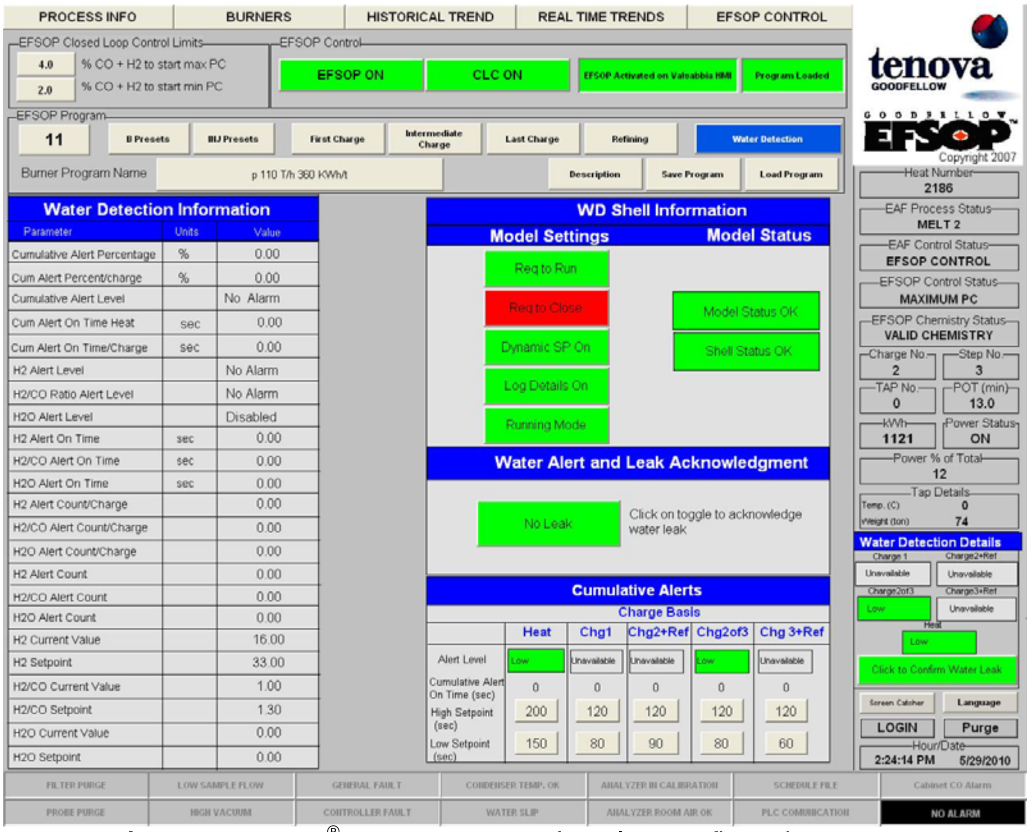


Figure 3. Example of H_2 Alert threshold bins for single charge.

The alert thresholds are generated based on the statistics from the fingerprint of historic heats. A dynamic model based on a moving window of historic heats continuously updates the alert thresholds on a heat by heat basis to account for changes in the process, scrap mix and seasonal variations. The size of the moving window can also be adjusted to influence the sensitivity of detecting abnormal water conditions. A smaller window of heats will improve the sensitivity of change, but will also generate more false alerts on every instance a change in the level of water is detected. A larger window will decrease the sensitivity to change over the given number of heats and reduce the occurrence of false alerts.

For operations with significant process changes, a larger moving window can be suggested and the sensitivity can be further improved for these types of operations by segregating the different operations into identifiable practices. This information can then be used to automatically call up different water detection alert thresholds for the identified practice. This feature has been built into the EFSOP® water detection application.

In addition, the EFSOP Water Detection Technology™ provides tiered alerting levels to indicate the probability of an actual abnormal water event. The tiered alerting provides three levels of alerts (low, medium, high) based on the duration of the heat or charge in an alert condition (cumulative alerting of both H_2 and H_2/CO metrics). The user has the ability to define the duration as a percent of power on time to trigger a medium and high level alert. The low level alert condition is triggered on the occurrence of an alert condition greater than the minimum wait time (in seconds) to alert. Figure 4 provides an example of the EFSOP® HMI water detection alert configuration screen.



EFSOP Closed Loop Control Limits
4.0 % CO + H2 to start max PC
2.0 % CO + H2 to start min PC

EFSOP Program: 11
Burner Program Name: p 110 T/h 360 KWh/t

Water Detection Information

Parameter	Units	Value
Cumulative Alert Percentage	%	0.00
Cum Alert Percent/charge	%	0.00
Cumulative Alert Level		No Alarm
Cum Alert On Time Heat	sec	0.00
Cum Alert On Time/Charge	sec	0.00
H2 Alert Level		No Alarm
H2/CO Ratio Alert Level		No Alarm
H2O Alert Level		Disabled
H2 Alert On Time	sec	0.00
H2/CO Alert On Time	sec	0.00
H2O Alert On Time	sec	0.00
H2 Alert Count/Charge		0.00
H2/CO Alert Count/Charge		0.00
H2O Alert Count/Charge		0.00
H2 Alert Count		0.00
H2/CO Alert Count		0.00
H2O Alert Count		0.00
H2 Current Value		16.00
H2 Setpoint		33.00
H2/CO Current Value		1.00
H2/CO Setpoint		1.30
H2O Current Value		0.00
H2O Setpoint		0.00

WD Shell Information
Model Settings
Model Status

Water Alert and Leak Acknowledgment
Click on toggle to acknowledge water leak

Cumulative Alerts
Charge Basis

	Heat	Chg1	Chg2+Ref	Chg2of3	Chg 3+Ref
Alert Level	Low	Unavailable	Unavailable	Low	Unavailable
Cumulative Alert On Time (sec)	0	0	0	0	0
High Setpoint (sec)	200	120	120	120	120
Low Setpoint (sec)	150	80	90	80	60

Heat Number: 2186
EAF Process Status: MELT 2
EAF Control Status: EFSOP CONTROL
EFSOP Control Status: MAXIMUM PC
EFSOP Chemistry Status: VALID CHEMISTRY
Charge No.: 2
Step No.: 3
TAP No.: 0
POT (min): 13.0
kWh: 1121
Power Status: ON
Power % of Total: 12
Tap Details
Temp. (C): 0
Weight (ton): 74

Water Detection Details
Charge 1: Unavailable
Charge2+Ref: Unavailable
Charge2of3: Low
Charge3+Ref: Unavailable
Heat: Low

Hour/Date: 2:24:14 PM 5/29/2010

Figure 4. EFSOP® HMI Water Detection Alert Configuration Screen.

The configuration of the tiered alerting allows the plant to decide on the appropriate action to be taken in response to the alert level and furnace operating conditions. Alerts triggered for known abnormal water events such as rain water or snow contained in the charge can be explain the and as such the operator response can be more conservative. Whereas consecutive abnormal water alerts triggered for each charge or heat without explanation may prompt a more serious response to stop and investigate for possible leaks.

The EFSOP Water Detection Technology™ has the ability to discount heats within the moving window that will not be incorporated into the dynamic model for alert threshold generation. This feature is critical in the event of an actual water leak event, in which case the user would not require the dynamic model to adjust alert thresholds to higher values. The trigger to discount heats is based on operator input on the EFSOP® HMI as shown in Figure 4.

3.2 EFSOP® Water Detection Testing

The EFSOP Water Detection Technology™ was tested via controlled water injection trials through the slag door. Approximately 50L/min of water was injected through the slag door as soon as possible after startup. Due to slag exiting the furnace at the end of charges and refining, trials were only conducted in the first and second charges and water injection into the furnace was stopped before the end of the charge. The algorithm was able to distinguish the charges with water injection from those without by means of an increased alert on time.

Additional water was also injected into the furnace by increasing the flow of electrode spray water. The normal electrode spray water used by the plant was approximately 30L/min. The electrode spray water flow was doubled therefore simulating the injection of 30L/min bringing the total electrode spray water to 60L/min. In most heats where this injected method was tested, an increased alert on time was noted.

3.3 Results and Discussion

Results were analyzed based on difference in concentration of H_2% with and without water injection as well as the difference in ratio of H_2/CO in normal operating conditions to conditions where excess water is present.

Figure 5 shows the off-gas analysis trend for H_2% in two different charges, the setpoints for H_2% in both charges, and the period in which water was injected via the slag door. The darker (blue) line indicates the H_2%. dynamic setpoint that was calculated by the EFSOP® Water Detection Technology ™ whereas the lighter line indicates the actual H_2% read by the EFSOP® off-gas analysis system in that specific charge. It is noted is that in the later part of the first charge, where flat bath conditions exist, the current value is often over the H_2%.setpoint line. In this case the alert for H_2% was triggered continuously during the flat bath conditions.

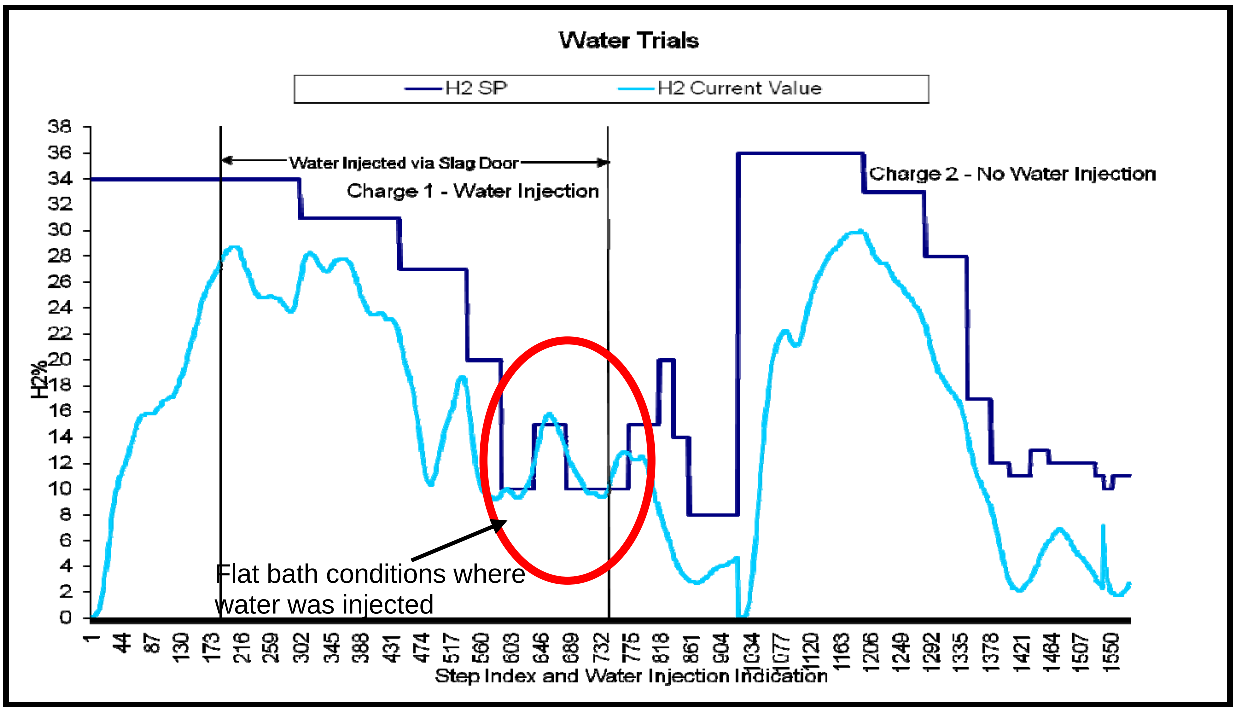


Figure 5. Example of H_2 % trend relative to the set-point during water trials.

Similarly, Figure 6 below shows the results of the water injection trial when analyzing H_2/CO. The H_2/CO setpoint generated by the EFSOP Water Detection Technology™ is indicated by the orange line and the calculated real time H_2/CO value for the heat is indicated by the yellow line. During flat bath conditions when the water was being injected through the slag door, the H_2/CO alert was being triggered continuously. These trials were repeated in multiple heats with similar results.

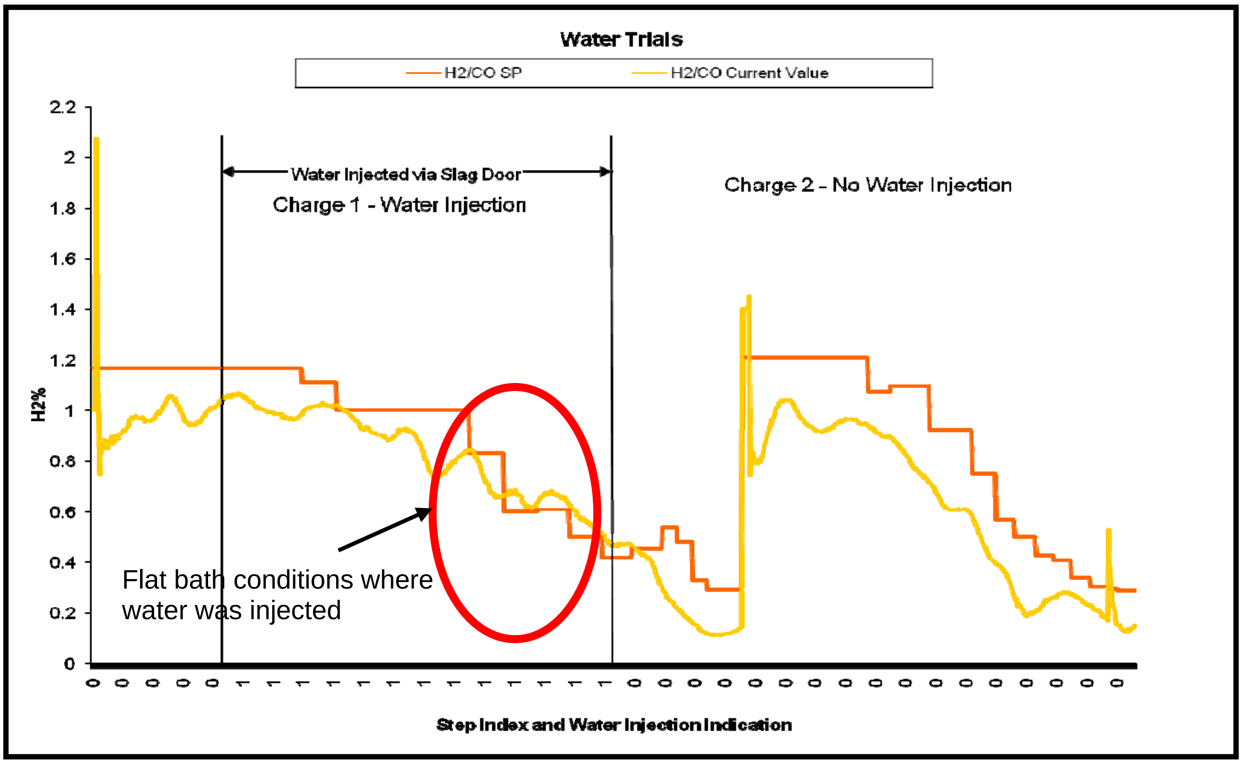


Figure 6. Example of H_2/CO trend relative to the set-points during water trials.

Following the slag door water detection trials, a water leak occurred in the furnace and the heat number was noted by the operator. Further analysis of the data revealed that the alerting increased significantly two heats before the operator noted the leak was present. Due to the fact that the water detection alerts were not online for the operator to use, it cannot be 100% certain that the system detected the leak in real time but it is highly likely that system accurately detected the water leak.

3.4 Conclusion of the Water Detection Module

Abnormal water events in a furnace can be detected using a statistical analysis of H_2%and the ratio of H_2/CO. The trials and results discussed above gave very optimistic results for the online detection of abnormal water events. The water detection software is currently being tested and further tuned to better quantify the false alert rate before being implemented by the plant for on line real-time abnormal event detection.

Acknowledgements

The authors would like to thank the maintenance, operators and production personnel at Ferriera Valsabbia for their support during the optimization and water detection testing phase. In particular, Franco Fusi for providing maintenance to the system and for his help during water trials and Pierluca Levrangi, for his collaboration and technical support.

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