Heraeus

Electro-Nite

Celox®
Celox SLAC®

Monitoring oxygen activity in steel and slag throughout the steel making process

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Steel making and steel refining are characterised by various oxidation and reduction processes coinciding with changes in the oxygen activity in the liquid steel and slag. Production cost, yield, and steel cleanliness widely depend on comprehensive and reliable oxygen control.

Continued improvement in product performance and unmatched quality monitoring has made the Heraeus Electro-Nite Celox® precision oxygen sensor the world industrial standard to monitor and control oxygen activity in both steel and slag in primary and secondary liquid steel production.

Celox® oxygen control in liquid steel

The Celox® sensor after an oxygen measurement

Principle

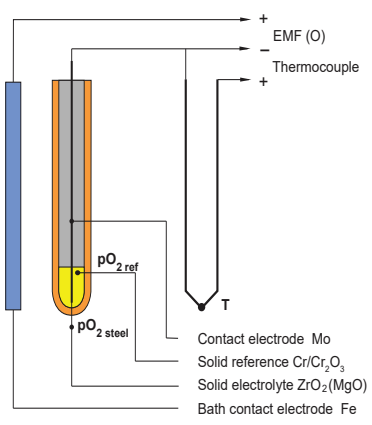
An integrated electrochemical cell provides a characteristic voltage that depends on the liquid steel's oxygen activity. This voltage is in reference to an approved oxygen standard (pO_{2ref}) within the cell. The generated electromotive force (EMF) or cell voltage in mV has a direct correlation to the partial pressure of the oxygen in the liquid steel (pO_{2steel}).

$$EMF = \frac{R*T}{n*F} \ln \frac{pO_{2steel}}{pO_{2ref}}$$

The Nernst's law

EMF: electromotive force measured by Celox®
T: steel temperature measured with Celox®
pO_{2ref}: partial pressure of O2 in a reference material
pO_{2steel}: partial pressure of O2 in the steel
R: the gas constant
F: the constant of Farady
n: the number of transit electrons per standard reaction

Celox® principle Scheme



Applications

Decarbonization control in BOF and EAF
When producing low carbon heats in electric furnace or converter, it is important to have a quick and accurate method for oxygen and carbon determination in order to save time and energy.

A Celox® measurement is the quickest way to determine oxygen activity and carbon content compared to sampling and analysis in the laboratory.

Using Celox®, the steelmaker can tap the converter or EAF without waiting for the final sample analysis. This practice allows the reduction of tap time by 5 to 10 minutes. This results in increased productivity and steel output (additional 3-4 heats per day), as well as energy and refractory savings.

Important:
Celox® has a high precision to determine the carbon content up to 0.15%C. Higher carbon contents can be more precisely determined using Tap-Tip sensors.

Deoxidation control at the ladle treatment station by Celox® allows:
For Al-killed steel grades (slab casters):
- Fast soluble Al measurement which can save several minutes per heat
- Online calculation of the necessary Al additions to kill the steel, to reduce the a(O) to nearly zero as well as calculation of Al to reach the aimed Al level
- Steel cleanliness evaluation: the difference between the total Al (sample analysis) and soluble aluminum (Celox®) gives the steelmaker an idea about the steel cleanliness. At the end of the ladle treatment both values should be within 0.001%.
- Improve desulfurization efficiency: Celox® measurement helps to achieve the lowest active oxygen content before the treatment (for deeper desulfurization) by controlling the aluminum additions

For Mn-Si-killed steel grades (billet casters):
- Increased steel quality: a correct setting of the oxygen content will decrease the number of blowholes
- Avoid casting problems: Reduced break-out risk and tundish nozzle clogging risk
- Improved steel cleanliness by carefully carried out deoxidation practice

Decarburization control at degassing stations
Celox® utilization before RH degassing allows more efficient and lower cost decarburization by providing a fast a(O) measurement which makes the process more predictable. Fast calculation of necessary Al addition before Ti addition helps to save expensive materials and produce steel within narrow composition specifications.

Oxygen control in non-ferrous metals and slags
Celox® provides accurate measurements of active oxygen content in various non-ferrous melts and their slags, such as Cu, Ni, Pb, etc.

These applications use specially designed Celox® sensors, be sure to review with your local technical representative.

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Celox® versions

- Celox® High: for measurements over 50 ppm active oxygen and carbon determination in BOF and EAF
- Celox® Al: for measurements in 1…2000 ppm range, carbon determination in BOF and EAF, and aluminium measurements in Al-killed steels (LF, VD, RH)
- Celox® Ti: for aluminium control in IF steels (if Ti>0.02%)
- Celox® Tundish: for measurements in 1…2000 ppm range at lower temperatures (<1570°C)
- Celox® for specific lance and hardware configurations (for various manipulators and robots)
- Celox SLAC®: for oxygen control in slag
- Celox® HotMetal: for %Si or %S measurements in hot metal

Celox® is available with thermocouple calibrations S, R, and B in various cardboard lengths and diameters for all possible applications.

Description of a typical measurement system

- Celox® sensor
- *i*M² SensorLab® measurement instrument
- Immersion lance with appropriate interior and exterior compensation cables
- Wireless Qube or wired connection of the lance with measurement instrument

Measurement time	3 … 12 seconds	
Oxygen activity	range	+300 … -300 mV
	range	1…2000 ppm
	accuracy	2 mV
Temperature	range	1100 °C…1768 °C (type S, R) or 1820 °C (type B)
	accuracy	0 °C…3 °C
Carbon (calculated)	range	0,02 %…0,15 %
	accuracy	10 % of measured value
Aluminium (calculated)	range	0 %…0,02 %
	accuracy	10 % of measured value

* Specifications for different Celox® versions are various, please ask Heraeus Electro-Nite for details

Measuring instrument *i*M2 Sensor Lab® and Celox SLAC® sensor

Celox SLAC® application in metallurgical slags

An additional benefit for the steelmaker in the production of high quality steel is the use of a Celox® sensor for measuring free oxygen in steel jointly with a Celox SLAC® sensor for measuring active oxygen in slag. Two consecutive measurements will help to find out the oxidizing ability of the slag in relation to the steel, which will prevent the secondary oxidation of steel and all the negative consequences of this phenomenon.

Principle

The working principle is identical to Celox® for steel, and the measuring element – the cell, is the same as in the Celox® Al sensor, but has:

- An exposed zirconia cell to pick up slag during immersion
- No thermocouple

Celox SLAC® can be used with standard Celox® hardware and instrumentation.

Applications

Combined use of Celox® and Celox SLAC® sensors in the secondary metallurgy allows:

- Increased efficiency of steel desulfurization by keeping the active oxygen levels of steel and slag at a minimum
- Improved steel cleanliness via accurate calculation and addition of deoxidizers to the slag which eliminates secondary steel oxidation and the formation of detrimental oxides
- Increased yield of added ferroalloys via the precise deoxidation of the slag before additions
- Prediction of aluminum fade
- Avoidance of nozzle clogging during casting
- Savings of Al during deoxidation
- Fast determination of FeO and Fe+MnO in slag eliminates time consuming, expensive, and sophisticated X-ray analysis

At the Electric Arc Furnace

Fast FeO measurements can improve iron yield. The Celox SLAC® sensor can be used on a hand lance or via a robot through the slag door or EBT side to control the FeO content of slag. The rapid measurement (10sec) provides time to react if the FeO content is too high – oxygen blowing can be reduced to minimize excess slag oxygen. Alternatively, carbon can be blown into the slag to reduce FeO, pushing iron from the slag back into the steel, thereby increasing the iron yield of the heat.

Celox SLAC® Specifications

Measurement time	6 … 12 seconds	
Oxygen activity	range	+300 … -300 mV
	accuracy	2 mV
FeO	range	0.2…50%
	accuracy	10 % of measured value

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