MD0014.2

EMC

Analysis & Control

Hydrogen in liquid aluminium

HYCAL™

HYCAL ™ a portable analyser for the real-time measurement and control of dissolved hydrogen in liquid aluminium alloys.

The control of dissolved hydrogen in liquid aluminium alloys is a critical requirement for the aluminium industry. Aluminium producers and foundries worldwide make significant investments in capital equipment, consumables and human resources in order to ensure that the dissolved hydrogen content is within acceptable limits.

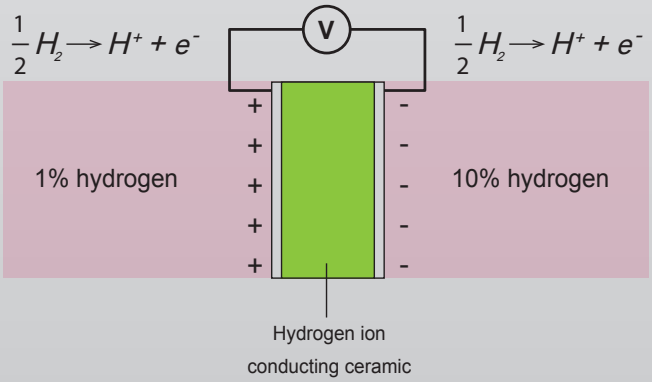
If the hydrogen level is too high, during solidification, there is the potential for the formation of cavities / pores. Conversely, a moderate hydrogen level may be desirable under certain conditions, in order to combat shrinkage porosity. As such, there is an optimum hydrogen level which ideally should be established and controlled during casting. Although dissolved hydrogen is critical, pore formation is also influenced by several other factors, the most significant being melt cleanliness i.e. the level of inclusions such as metal oxides.

Hydrogen measurement techniques such as the 'reduced pressure test' provide an indication of the combined effect of both the hydrogen content and the metal cleanliness. However, in order to be able to **analyse** the hydrogen content specifically, it is necessary to measure it directly. Furthermore, in order to **control** the hydrogen content, it is necessary to measure it accurately in real-time.

The most accurate, reliable and cost effective solution is the ***HYCAL*** ™

Principle of measurement

The technology is based on a novel ceramic material ($CaZrO_3$-In) which, at an elevated temperature, is able to conduct hydrogen ions. The principle behind how this material can be used to measure hydrogen concentration is shown below:

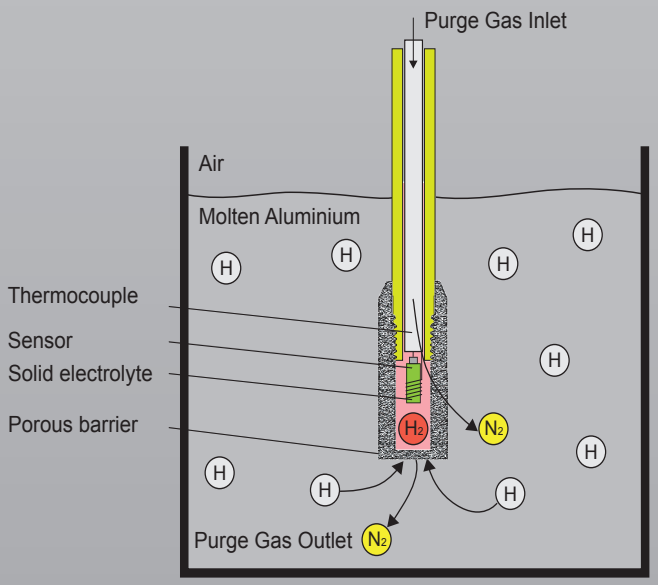


Above, an impervious section of hydrogen ion conducting ceramic (green) is coated with metal electrodes on both faces. The concentration of electrons is higher on the right side than on the left due to the greater hydrogen concentration. This results in the right side becoming negatively charged with respect to the left. If the voltage across the ceramic is known and the hydrogen concentration on one side is known (the "reference" hydrogen concentration), then the hydrogen concentration on the other side can be calculated. This type of arrangement is called a "hydrogen concentration cell".

In order to be able to use a hydrogen concentration cell to measure hydrogen, the reference hydrogen concentration must be known. A patented "Solid State Reference" (solid material which generates a known hydrogen concentration) is sealed within the sensor to effect this reference. The electrode exposed to the solid state reference is thus the "Reference Electrode" and the electrode exposed to the measured gas is the "Measuring Electrode".

The schematic below shows the arrangement of the probe during measurement of hydrogen concentration in molten aluminium.

At the end of the probe there is a porous diffusion barrier. Hydrogen dissolved in the melt comes out of solution and the hydrogen gas forms within the measurement chamber as shown. The measuring electrode of a hydrogen concentration cell is exposed to this gas. The voltage from the hydrogen concentration cell is measured and as the reference hydrogen concentration is known, the concentration of hydrogen gas in the measurement chamber is calculated. To work out the hydrogen concentration in the melt, the solubility of hydrogen must be known. The solubility of hydrogen in pure aluminium is dependent on temperature. Therefore the melt temperature must also be measured in order to calculate the dissolved hydrogen level. Hydrogen solubility also depends on the alloying components in the melt. In this respect, an adjustment is made to solubility factors within the analyser to compensate accordingly.



Hycal probe

The standard lengths are 300mm and 400mm for the ceramic and steel sections respectively.

The split-line identifies the sections where non-standard lengths are also available upon request.

Features:

- **Plug and play** — No assembly required. Simple to use, as per standard thermocouple.
- **Durable** — Chemical attack and impact resistant.
- **Economical** — Typically, 100 measurements or 20 hrs cumulative use, whichever the sooner.
- **Fast** — Initial stable reading < 5 mins typical, response time thereafter < 5 secs.
- **Versatile** — Can be used for spot checks and or continuous monitoring. The probe can be mounted on the arm of the analyser or separate custom clamp and even held by hand throughout measurement if preferred.
- **Traceability** — Calibrated reference gases may be purged through the probe (in situ) to verify sensitivity, response time and accuracy of the probe.

Hycal analyser

The Hycal analyser has been specifically developed to meet the requirements of the production environment in both the casthouse and the foundry:

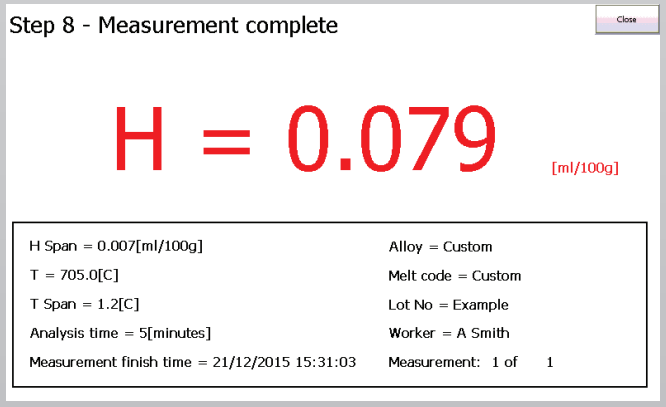
There are two models: a portable analyser ‘Hycal’ (above left) and a panel-mounted version, ‘Hycal 1000’ (above right). Whilst the internals of each version are essentially identical, the general concept of the Hycal’s design is to minimise size and weight. The Hycal 1000 series, with its more spacious, modular design is significantly larger and heavier yet lends itself more readily to the customization of its outputs such as on-demand actuation of the probe or for the control of degassing equipment and is therefore normally used as a fixed installation.

Analyser features:

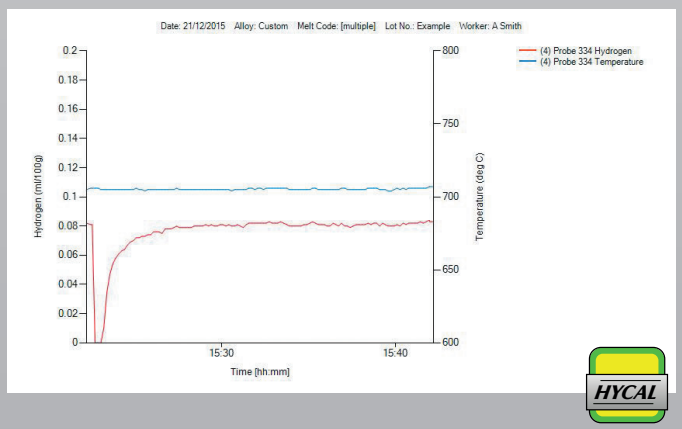
- **Portable** — No connections required whatsoever. Battery powered. Internal gas cylinder.
- **Durable** — Withstands arduous working environment (up to 70 deg C).
- **Remote Control** — Included PC software allows every function to be viewed and controlled from a remote location, such as control-room or office.
- **SCADA** — Easy integration into an existing SCADA system (MODBUS TCP protocol).
- **User Interface** — A sophisticated user interface has been developed specifically to meet the requirements of the production environment at the operator level. Security is controlled by login based access privileges (Operator / Manager / Engineer).
- **OBD** — Sophisticated On-Board Diagnostics constantly monitor the probe's impedance, flow rate and internal pressure etc and outputs the appropriate alarm message with suggested remedies, should an issue arise - such as the the prompt to change probes when maximum use has been detected.
- **Control** — Can be used to control hydrogen during a 'degassing' or 'gassing-up' procedure. Rather than operate a treatment for a fixed amount of time, with Hycal it is possible to define a setpoint in terms of hydrogen content.

Guided measurement

In close co-operation with its customers, EMC has developed a sophisticated optional user interface which guides the operator through a number of 'steps' from the selection of the alloy and lot number through to the final result which outputs and logs an averaged hydrogen value plus other statistical data such as the span (max. minus min. value), analysis time and temperature range during the analysis etc.



PC software



The data within the Hycal is stored in a protected format such that only validated data can be imported into the PC software thus providing data archiving security.

The software is very simple to use. All the data from multiple analysers and probes can be searched via melt code and lot number, probe number etc can be filtered thereafter. Either a graphical (as shown left) or spreadsheet report can be generated.

Calibration service and repair

EMC operate an accredited ISO9001:2008 quality system.

A calibration service is offered, traceable to international standards. Typically an annual service and calibration is required and in this case a replacement Hycal system can be provided during the interim to avoid any downtime.

A calibration certificate is provided for all analysers and probes as standard.

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Technical specification

Hydrogen Measurement

Sensor type	Electrochemical. Solid-state reference.
Unit of measurement	ml/100g [@ 20°C and 1 atm] (milliliter of hydrogen per 100 grams of liquid aluminium)
Reproducibility	±0.01 ml/100g or 3% of hydrogen concentration
Response time	Initial result: 5 minutes typically. Subsequent response: < 5 seconds
Temperature of operation	620°C to 800°C

Mechanical

Analyser	340(W) x 266 (H) x 223 (D) mm. / 8 kg.
Probe	Standard length: 750mm. Maximum depth of immersion: 300mm Diameter: 6mm
Probe cable (std)	1170mm
Refillable gas bottle (300ml)	Dry argon or nitrogen. Max fill pressure: 120 bar

Temperature Measurement

Thermocouple	Type K
Specified limits of error	1.1 deg C or 0.4% - whichever the greater

Electrical

Power supply (external unit)	AC 85 - 265 V, 47 - 63 Hz
Typical power consumption	< 10 W (probe heater off, battery discharging)
Max. power consumption	210 W (probe heater on, battery charging)
Battery chemistry	Lithium ion
Battery life	8 - 14 hours (depending on screen brightness)
Screen lighting	LED
Screen resolution	800 x 480 WVGA, TFT colour LCD
Screen size	7” (177mm) diagonal
Touch screen type	Analogue-resistive with 4H hardness
Ethernet interface	10/100 Base-T, RJ45
Communication protocol	MODBUS TCP
USB	2.0 full-speed (Type A)
Operating Temperature	0 - 70 deg C
Humidity	5 - 95% non-condensing

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