Hyindoor

Pre normative research
on the indoor use of fuel cells and
hydrogen systems

Sensor performance assessment

Valerio Palmisano /Eveline Weidner /Lois Brett /Christian Bonato /Freek Harskamp

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New Energy World JU
fuel cells & hydrogen for sustainability

Sensor activities for Hyindoor

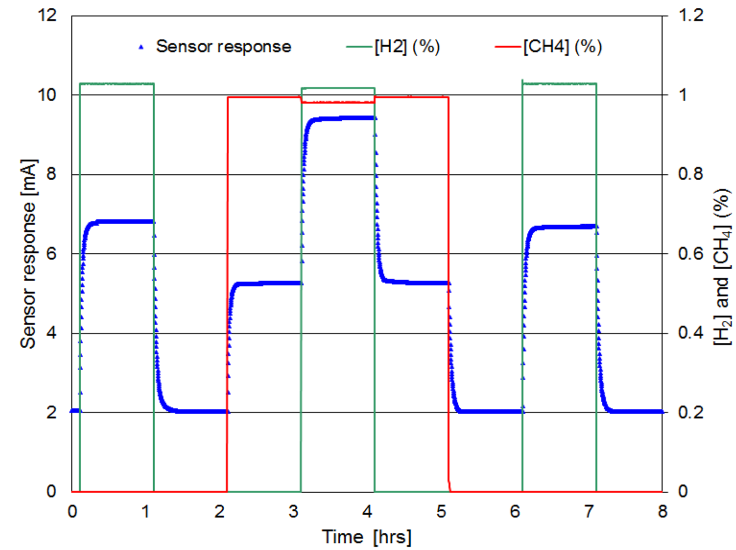
- Market survey: 112 sensors identified
- Identification of performance requirements for indoor applications
- Recommendation: 5 suitable sensor models were selected
- Identification of required performance tests
- Sensors performance validations

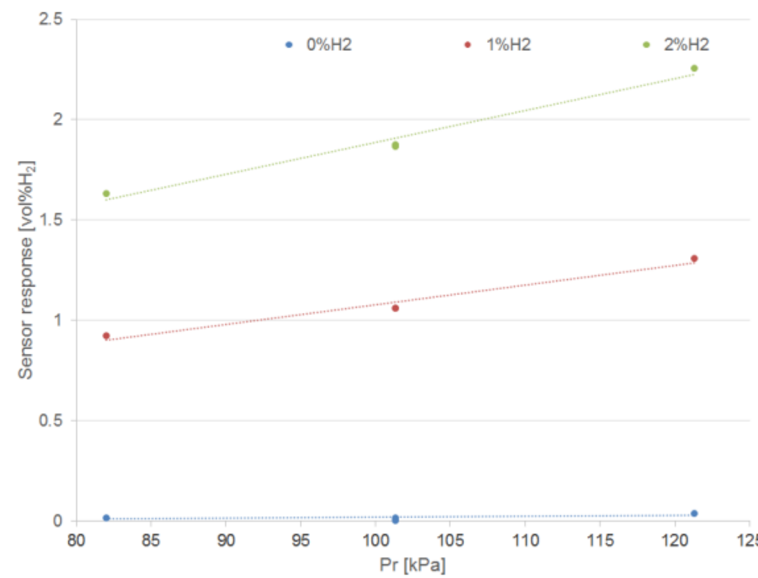
Mature technologies for sensing H_2

Thermal Conductivity (TCD)	H_2: highest thermal conductivity of all known gases. $[H_2]\uparrow \rightarrow T\uparrow$ at sensing point, detected through a Wheatstone bridge.
Catalytic (CAT)	A sensing element detects the heat of combustion of H_2 with O_2 at the Pd/Pt catalyst.
Semiconductive Metal-Oxide (MOX)	Hydrogen gas reacts with chemisorbed O_2 in a semiconducting material and changes the resistance of the material.
Electro-chemical (EC)	Oxidation of H_2 at the sensing electrode producing a current proportional to $[H_2]$. Counter reaction at the cathode (reduction of O_2)
Metal Oxide semiconductor (MOS)	3 layers structure: metal-insulator (oxide)-semiconductor. H_2 dissociates at catalytic metal (Pd) giving rise to a H-dipole layer (at the interface) → work function changes
Pd Thin Film (PTF)	Relates the resistance of a Pd-based thin film to the external concentration of H_2

Tests performed

- Accuracy/Linearity
- Short term stability
- Pressure
- RH
- Temperature
- Lower Detection Limit (LDL)
- Contaminants:
  - CH_4 (1%)
  - SO_2 (0.05%)
  - CO (0.005%)
  - HMDS (0.001%)
- Response/Recovery time
- Influence of gas flow
- Influence of orientation





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Cross sensitivity / poisoning

Cross-sensitivity (i.e. selectivity): ability of a sensor to respond to the target analyte, regardless of the presence of other species.

Cross-sensitivity and resistance to poisons are considered important by sensor end-users because can lead to:

- Undetected hydrogen leaks, with serious safety consequences (false negative)
- False alarms, with economic damage (false positive)

Other species which **permanently** affect a sensor response are defined as *poisons.*

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ISO requirements

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Test	Requirement for 0.05 < $[H_2]$ < 2%	Requirement for 0 < $[H_2]$ < 150 ppm
Accuracy **(>5 points / order of magnitude)**	|Variation| < $[H_2]/4$	|Variation| < $[H_2]/2$
STS **(5 cycles or more)**	|Variation| < R/10 (R = Sensor response)	|Variation| < 50 ppm (R = Sensor response)
Temperature **(-20 <T< 50ºC)**	|Variation| < 0.2*R (R = Sensor response at 20ºC)	|Variation| < 50 ppm (R = Sensor response at 20ºC)
Pressure **(80 <p< 110 kPa)**	|Variation| < 0.3*R (R = Sensor response at 100 kPa)	|Variation| < 50 ppm (R = Sensor response at 100 kPa)
RH **(20 < RH < 80%)**	|Variation| < 0.3*R (R = Sensor response at 50%)	|Variation| < 50 ppm (R = Sensor response at 50%)
Flow rate **($0.5*F_0$ < F< $1.3*F_0$)**	|Variation| < R/4	|Variation| < 100 ppm
Selectivity **(CH_4, CO)**	|Variation| < R*/10	|Variation| < R*/10
Poisoning **(500 vppm SO2, 10 vppm HMDS)**	|Variation| < R*/5	|Variation| < R*/5

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Results reporting

Performance parameter	Cat-1	Cat-2	Cat-3	TC	EC
Manufacturer Calibration	**x**	**X**	×	√	**X**
Accuracy and Precision	√	×	×	√	×
Short term stability	×	√	√	√	x
Pressure	√	×	×	√	
RH	√	×	√	×	×
Temperature	**x**	√	×	√	X
Lower Detection Limit (LDL)	**50 ppm**	**50 ppm**	**500 ppm**	**50 ppm**	**<<50 ppm**
CH4 (1%)	**X**	**X**	**X**	**x**	**No**
SO2 (0.05%)	**X**	**No**	**small**	**No**	**X**
CO (0.005%)	**No**	**No**	**No**	**No**	**lower**
HMDS (0.001%)	**No**	**No**	**small**	**No**	**No**
Response/Recovery time	**6 s**	**~10 s**	**~10 s**	**4 s**	**~50 s**
Influence of gas flow	**0.16**	**0.08**	**0.13**	**0.03**	**0.39**
ATEX	**IEC60079-15**	√	√	**No**	√

■ = failure (ISO26142) ■ = dependence ■ = stable ■ = highly stable

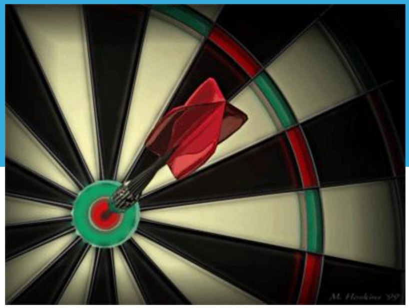
Guidelines for the deployment of sensors

Placement and number of the sensors in a confined space

The two basic approaches to the location of gas detectors are

1. **Point source monitoring**, where the sensor is sited close to an identified potential leakage point

2. **Perimeter or area monitoring** for extensive areas, where a plant or process is ringed by monitors or a network of sensors is deployed to give early warning of a leak



General considerations for sensor placement

- The position of the sensor should be on or close to the ceiling
- If possible, the position of the sensor should be placed just above possible sources of leak, such as valves and gaskets.
- Attention should be given to ventilation patterns
- Consideration of openings in the enclosure (doors, windows...)
- Areas not reached by the ventilation system need to be monitored by additional sensors

Alarm set points

- For leak detection two alarm levels can be set.
- Depending on the application, for example:
  - first alarm level at 10% of the lower flammability limit
  - second alarm level at 25% of the LFL.
- The hydrogen sensor needs to be integrated with the general safety system, linked to appropriate measures.
- Visual and audible alarms should be provided as necessary.
- After an alarm has been triggered, persons re-entering an enclosed space should use a portable hydrogen detector.

Specific applications

Warehouse indoor refuelling:

- Variations of temperature and relative humidity
- Presence of potential poisons (siloxanes!)
- Ventilation patterns need to be analysed (do not place sensor in "dead corners")
- Beware of nearby openings, as hydrogen could be diluted
- If sensor is placed on the ceiling, it should be reachable for maintenance
- Network of sensors in case a large area needs to be monitored

Specific applications

Small scale reformer: sensor will require ATEX certification.

Fuel cell for back-up generation: Indoor placement of a fuel cell may require an automatic shutoff valve interlocked with gas detection (check applicable regulation)

Fuel cell container: Typically outdoors, variations in T, RH. Gas detector mandatory for the fuel cell power system. Compliance to ISO 26142 or IEC 60079-29-1, as appropriate. Sensor needs large measuring range and resistance to poisons. Low power consumption important for off-grid systems.

Fixed indoor hydrogen energy based system: depends on ventilation, may need ATEX

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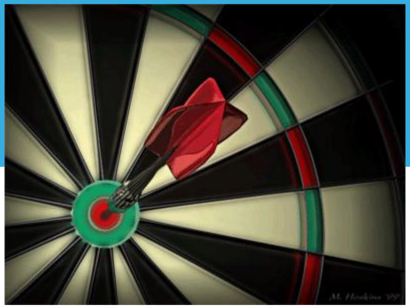
Thank you!

Questions?



General considerations for sensor placement

The sensors should not be positioned in areas where they may be susceptible to damage through vibration, heat, contamination or water damage

The sensor orientation will be specified by the manufacturer. Typically they should preferably face down towards the area where the leak is expected.

The number and placement of sensors depends on the ventilation as well as the volume of the space and the leak rates to be monitored

CFD modelling could be a promising approach to optimize placement and number of sensors for complex installations

Gas detection in hazardous areas

- A gas sensor for use in hazardous areas should not provide a source of ignition. Look for “CE” and “Ex” markings

- In Europe equipment to be used in a potentially explosive atmosphere is covered by the EC directive 94/9/EC (ATEX Regulations). Hydrogen gas detectors used for safety shall comply with ISO 26142 and IEC 60079-29-1.

- When possible, the control panel should be located so that readings can be taken safely, outside the hazardous area.

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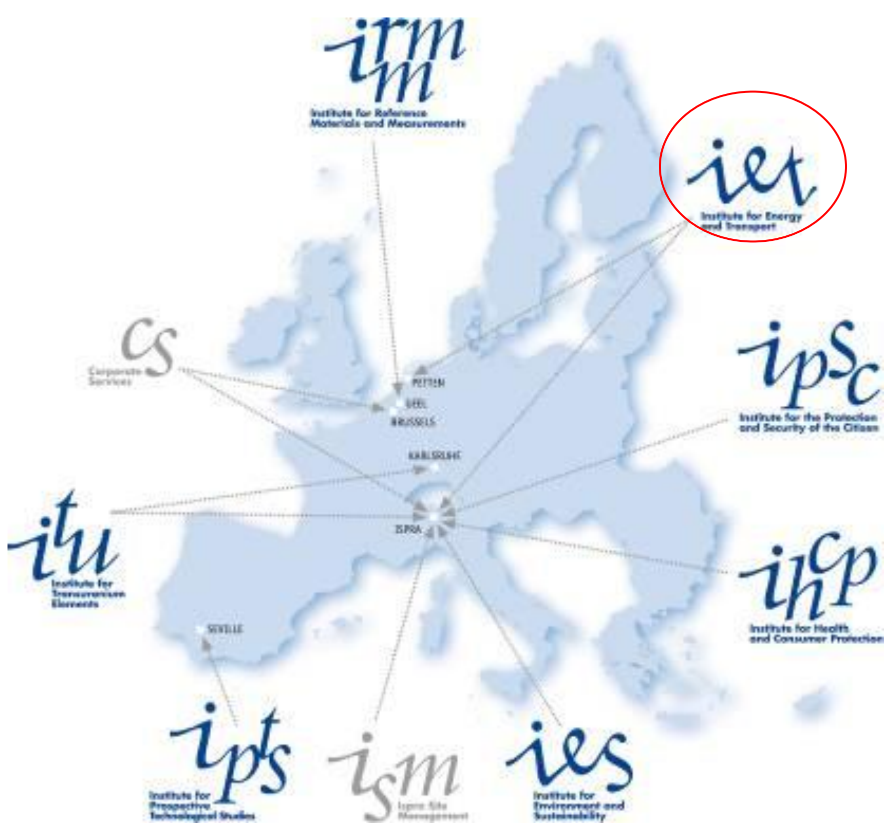
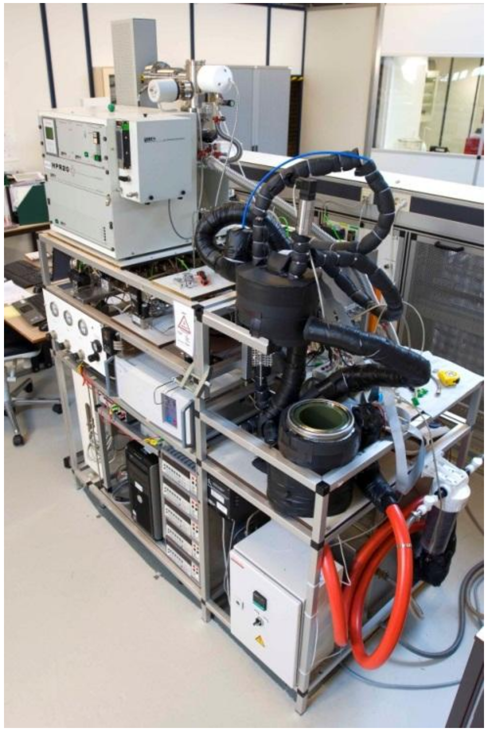


JRC- sensor testing facility (SENTEF)

- Performance testing of H_2 Safety Sensors
- Comparison of different sensing technologies
- Influence of ambient parameters/contaminants
- Sensor response/recovery time measurement



- Temperature: -40°C → +130°C
- Pressure: 1 → 250 kPa
- RH: 10% @ -40°C, 99% @ 60°C
- 4 MFCs for inlet gases (H_2, CO, CH_4, CO_2, SO_2,…)
- GC Gas analysis