Renewable Energy - HYDROGEN

Mass Flow and Pressure Measurement and Control

Bronkhorst®

Bronkhorst,

YOUR Partner for Hydrogen Measurement and Control

Why Bronkhorst?

- More than 50,000 instruments produced and delivered for hydrogen
- Flow Meters - Pressure Regulators - Flow Controllers - Control Valves - Humidifiers
- Instruments for hydrogen in laboratory, pilot plant and industrial installations
- 40 years of experience in hydrogen applications: fuel cells, electrolysis, storage, power to gas, H_2 catalysis, leak testing, humidification, and many more…
- Hydrogen calibrations
- Explosion protected, ATEX and FM certified executions
- Extensive fieldbus connectivity (Industrial Ethernet, CAN 2.0, Serial RS232/RS485)
- Worldwide factory level support, provided by more than 20 Global Service Offices

www.bronkhorst.com

Bronkhorst®

We understand hydrogen

With the widest product range of low-flow (mass) flow meters and flow controllers on the market Bronkhorst supports the hydrogen market in various applications. Since hydrogen is playing an increasingly important role in our energy system, we understand that further development of technology is a key factor. We proudly support research and improvement of key equipment used in generation, conversion & storage of hydrogen and enable this industry to upscale production and lower the costs in design.

In this market brochure, we would like to elaborate on some of these applications and the solutions that our instruments can provide.

› Examples of applications

For fuel cells
- Humidification of fuel cells
- Efficiency testing and quality control
- Research in poisoning with CO_2 or other gases
- Leakage testing of fuel cells stacks

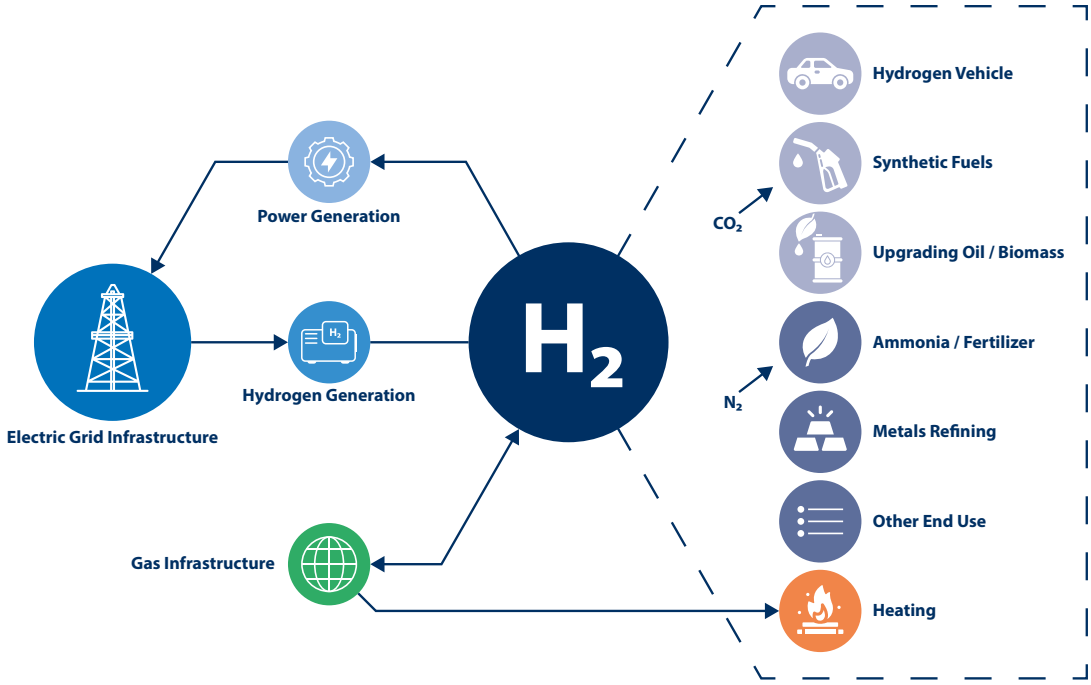
For hydrogen production
- Gas output monitoring (electrolysis)
- Natural power to gas with bacteria (conversion of H_2 and CO_2 to Methane)

For storage
- Hydrogen storage in metal hydride
- Hydrogen storage in liquid organic hydrogen carriers (LOHC)

Odorization of hydrogen with liquid or gaseous odorants.

Hydrogen as a key role for the energy transition

Bronkhorst supports a wide range of H_2 applications summarized in the overview below. The various applications all have specific requirements, e.g. focus on accuracy, reproducible flow rate, etc. Based on 40 years of experience, a hands-on mentality and an extensive range of low-flow products and solutions, we feel comfortable with each H_2 flow measurement or control challenge.



When you say hydrogen, you say Bronkhorst

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- More than 50,000 instruments produced and delivered for hydrogen
- Flow meters - Pressure regulators - Flow controllers - Valves - Humidifiers
- Instruments for hydrogen in laboratory, pilot plant and industrial installations
- 40 Years of experience in hydrogen applications
- Hydrogen calibrations
- Explosion protected flow meters/controllers for hydrogen (with ATEX, KCs, TIIS or FM approval)
- Worldwide factory support, provided by more than 20 Global Service Offices
- Sustainable relationship with suppliers and customers

Your advantages at Bronkhorst

- Largest portfolio of thermal mass flow meters and controllers for gases
- Excellent reproducibility and long-term stability
- Proven quality with innovative cutting-edge technology
- Flexible integration due to 10 available fieldbus options
- Userfriendly and ready to "plug and perform"
- Co-creation of customized manifold or open-frame solutions

APPLICATION NOTE

Humidification of fuel cells

Inside the engine of your car, gasoline reacts directly with oxygen from the air to cause a combustion which enables your car to drive. This is the conventional way. Chemical energy is converted into useful mechanical energy. A cleaner and more promising alternative to combustion is a fuel cell. Oxygen and fuel, such as hydrogen, are fed to the fuel cell to electrochemically react, forming electric energy with only one harmless byproduct, namely water.

As a result, electrons flow through an external circuit powering an electric motor. The chemical energy from the fuel is converted into electrical energy.

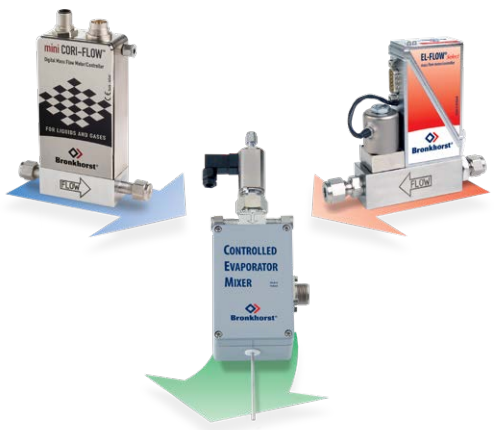
Fuel cells consist essentially of a stack of two electrodes with an electrolyte membrane in between. This electrolyte allows ionic species to conduct and generate power. In a polymer electrolyte membrane fuel cell - PEMFC - electrolytes need to be in a hydrated state to maintain a high ionic (proton) conductivity and, hence, optimal performance. Humidification of such a fuel cell is essential. This is a typical process used for both automotive and stationary applications.

Application requirements

Careful deterministic humidity control is essential to be able to design the most durable fuel cell for the specific application. Since the role of many input parameters such as gas flow, water vapour content and type of fuel cell is investigated, a broad range of gas flows is necessary - including small flows - and the working point needs to be changed quickly.

Important topics

- Quick change of working point
- Constant humidification possible, even at small flows
- Accurate control and measurement of media
- Quality assurance through all parameters



CEM
Liquid Delivery System with Vapour Control

Scan this code for more information.

Photo: Kurt Fuchs / Fraunhofer IISB

Polymer Electrolyte Membrane (PEM) Fuel Cell

APPLICATION NOTE

Leak testing of fuel cell stacks

The essence of fuel cells is that hydrogen and oxygen do not react with each other directly, but in an indirect and controlled way. These reactants are supplied to separate parts of the fuel cell, and they react with each other inside the fuel cell with water as reaction product and an electrical current as result.

To prevent a premature direct reaction of hydrogen and oxygen resulting in a lower performance of the fuel cell, there should be no short circuits leaks between the hydrogen and oxygen side, and each of the sides should not be blocked.

For car manufacturers it is important to work with high quality fuel cell stacks. Stacks are metal plates that are assembled in parallel to a fuel cell stack. The number of metal plates depends on the capacity. During the assembly, seals or other particles could have come between the plates, which is undesirable. Bronkhorst's distributor, Wagner Mess- und Regeltechnik, helped a car manufacturer by supplying instruments able to perform such a quality control.

Application requirements

Part of the incoming quality process of our customer is to check the quality of the fuel cell. A value for an optimum flow resistance window needs to be defined, and by applying a gas flow and measuring a pressure increase or drop, the flow resistance can be quantified. A too low flow resistance is a measure for a leak, and a too high flow resistance for a partly blocked fuel cell. These tests need to be performed at the hydrogen as well as the oxygen side of the fuel cell.

Important topics

- Reproducibility
- Purity of the gas
- Flow-pressure control
- Flexibility

Scan this code for more information.

EL-FLOW Prestige FG-201CV
Mass Flow Meter/Controller for Gases

APPLICATION NOTE

Power to gas

Developing more technology for sustainable generation of hydrogen is high on our global agenda. We support several (micro) biological research initiatives combined with our wide experience on fermentation processes for other industries. 'Power to gas' refers to the conversion of electricity to gas. A well-known example is using electricity for the electrolysis of water to generate hydrogen, with oxygen as a by-product. This hydrogen can be used as it is – e.g. to feed fuel cells - but it can even go further. If the hydrogen subsequently reacts with carbon dioxide to methane, the latter can be introduced to the natural gas network. In countries like Germany and the Netherlands, there is an existing infrastructure to transport natural gas through pipes from the place where it is extracted or processed to the place where it is used – for central heating in houses or for the stove in the kitchen.

There are several companies developing technologies to have bacteria excrete methane based on hydrogen and carbon dioxide as their 'food'. This can be considered as a natural power-to-gas application for storing green electricity and a treatment technology for process gases containing carbon dioxide (CO_2) as well. Nature meets technology!

Application requirements

A major aim of the customers is to optimise the efficiency of the bacteria to convert hydrogen into methane. The process is first tested on a small scale in order to develop the optimal bacteria type. Optimisation parameters for this process are H_2 and CO_2 flow, type of bacteria, temperature and pressure. To this end, a solution is needed to accurately and reproducibly supply hydrogen (and carbon dioxide) to the bacteria-containing reaction vessel.

Important topics

- Reproducibility
- Operating under ATEX Zone 2 conditions
- Automation

Scan this code for more information.

IN-FLOW F-201AI
Industrial style Mass Flow Meter/Controller for gas

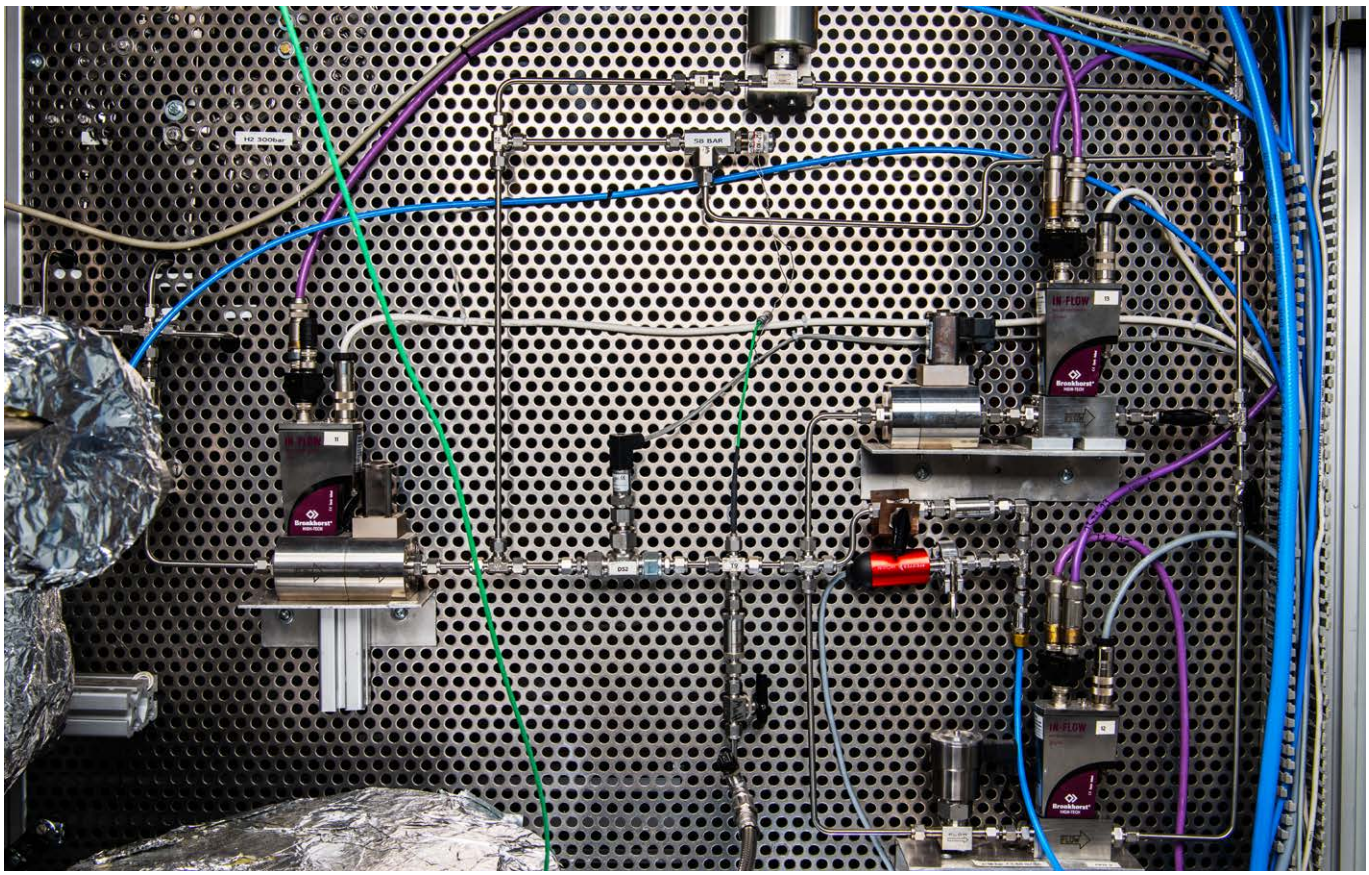


Photo: DLR Stuttgart - Institut für technische Thermodynamik

APPLICATION NOTE

Hydrogen storage in metal hydride

Our support continues in the development for more and better hydrogen carriers and process optimizations, for instance by the application of hydrides. Hydrogen-fuelled trucks, buses or cars are very much related to the common battery-powered 'electrical' cars that we see more and more every day. Hydrogen-fuelled vehicles are electrical vehicles as well, but the way of powering is somewhat different: hydrogen and oxygen react in a fuel cell to generate electricity that powers an electric motor. While battery-powered vehicles get their energy from pre-charged lithium ion batteries, the hydrogen for hydrogen-fuelled vehicles is nowadays generally stored in on-board pressurised tanks.

For a maximum energy density, the stored hydrogen needs to be compressed to pressures as high as 700 bar to be able to fit in the limited tank volume for an adequate mileage. These tanks need to be strong enough to withstand the high pressure and should also be imperviable to hydrogen to prevent the gas from leaking. However, to avoid safety issues related to the extreme pressure and to avoid wasting energy when compressing the hydrogen to that pressure, alternatives for these tanks are looked for.

Application requirements

In metal hydride containers, hydrogen is stored via reversible chemical reactions between a metal alloy and gaseous hydrogen. The solid metal hydride acts like a sponge that absorbs and releases the hydrogen. To investigate under which process conditions the loading/unloading of hydrogen works best, hydrogen flows and the process pressure need to be measured and controlled accurately. Furthermore, as we are dealing with an R&D environment, the setpoints and measurement values need to be recorded adequately for analysis purposes.

Important topics

- Flow-pressure control
- Reproducibility
- Secure method to store hydrogen
- Application at relative low pressure compared to traditional storage

Scan this code for more information.

IN-PRESS P-512CI
Industrial style Pressure Meter/Controller

APPLICATION NOTE

Hydrogen storage in Liquid Organic Hydrogen Carriers (LOHC)

Another example of a hydrogen carrier is LOHC which also can be used under normal atmospheric conditions. Whenever there is a time duration between the production of hydrogen and its use, the hydrogen needs to be stored in a certain location, preferably near the point of use. Some German companies and research institutes investigate a new way of storing hydrogen: in synthetic aromatic-based heat transfer oils that are normally used in bakery systems and other high temperature applications. Here the heat transfer oil acts as a liquid organic hydrogen carrier, LOHC.

The hydrogen is stored inside the liquid hydrogen carriers via a catalytic reaction. The liquid now has a low viscosity and looks like water. After the hydrogenation the viscosity has increased, and the liquid looks like honey.

When loaded with hydrogen, this LOHC is flame-retardant, which makes it a safe transport medium for hydrogen to the location of use where the hydrogen can be unloaded from this carrier liquid.

› Application requirements

The companies investigate at which pressure the reaction performs best for loading and unloading. To this end, accurate flows of LOHC and hydrogen must be supplied to the reactor. Tricky part here is the change of viscosity of the LOHC before and after the catalytic reaction. The mass flow instruments need to be able to cope with these viscosity changes.

› Important topics

- Ability to dose and pump viscous liquids
- Accuracy
- Mass flow instruments need to be able to cope with viscosity changes

Scan this code for more information.

MINI CORI-FLOW™ M14
Coriolis Mass Flow Meter/Controller for Liquids and Gases

Leader in low-flow measurement and control technology

Bronkhorst High-Tech is leading in the field low flow fluidics handling technology. We offer an extensive product range of thermal, Coriolis and ultrasonic flow meters and controllers for low flow rates of gases and liquids. Our flow instruments are used for a variety of applications in laboratory, machinery, industrial and hazardous areas. By sharing our knowledge and closely cooperating with OEM customers, we develop customer specific low flow solutions, e.g. of multifunctional, pretested modules or skids for gas, liquid of vapour flow control.

With our headquarters based in Ruurlo (NL), Bronkhorst is represented by 12 wholly owned subsidiaries in Europe, in the USA and in Asia and additionally by a network of distributors in more than 30 countries worldwide.

› Customer first

In addition to the extensive standard product range, Bronkhorst collaborates with customers to develop the best customized process measurement and flow control solution. Our global perspective, but with local focus, ensures that our international distributor network is able to provide on-site support and discuss the best solution to any given application. This ethos also includes product adjustments to ensure that the finer details of your application will always be met with a bespoke solution if necessary.

› Facts & figures

- 40 years experience in Mass Flow & Pressure
- More than 1.000.000 instruments in the field
- Approx. 460 employees at headquarters in the Netherlands
- 12 branch offices; approx. 150 employees
- Representation in >40 countries; >20 factory level service offices
- 20% of employees active in R&D and development
- Cleanroom according to ISO 14644-1 Class 6 with Class 5 flow benches
- ISO 9001 and ISO 14001 certified
- Bronkhorst Calibration Center, ISO 17025:2017

› Worldwide support

Support can be offered from many different locations around the globe. You can find our nearest distributor/service office on our web page www.bronkhorst.com/distributors

For urgent matters, our International Support Team is available 24/7 to answer your request immediately or ensure appropriate further action. Just call: +31 859 02 1866

Bronkhorst®

www.bronkhorst.com

Bronkhorst High-Tech B.V.
Nijverheidsstraat 1a
NL-7261 AK Ruurlo, The Netherlands

Tel. +31 573 458800
info@bronkhorst.com

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