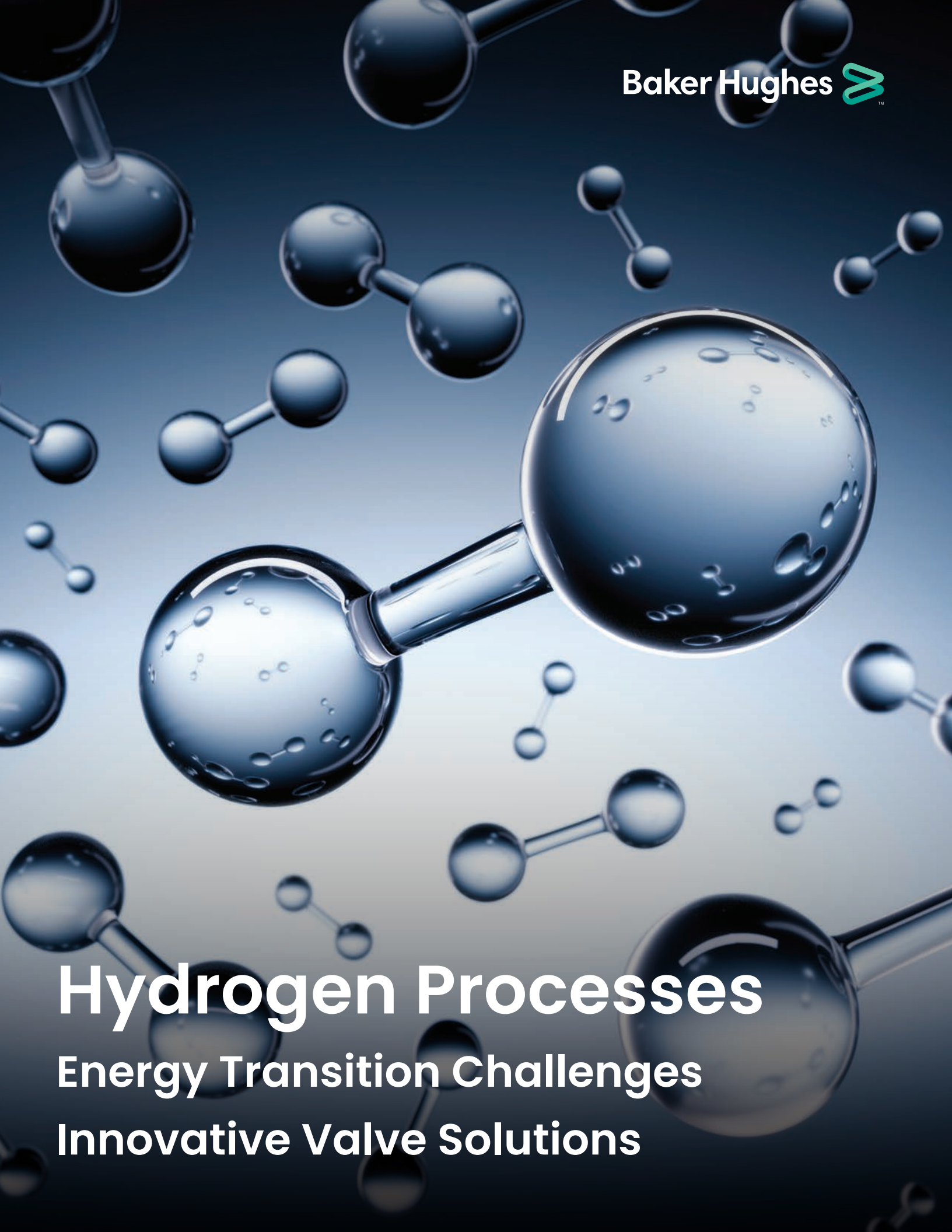


Baker Hughes

Hydrogen Processes

Energy Transition Challenges

Innovative Valve Solutions

Baker Hughes is looking to the future

The world is rapidly changing. In the dynamic environment of Energy Transition, it's more important than ever to innovate and provide solutions that help our customers face new challenges with confidence in their process applications.

Optimize Service

Improve Reliability

Increase Efficiency

Reduce Emissions

Any process that moves or stores hydrogen requires a valve. You need to be assured that when designing systems for hydrogen production, transportation or storage you've got the best and safest in control and pressure relief.

Optimize Service

Our digital suite of Valve Lifecycle Management tools coupled with our global network of Masoneilan™ Authorized Repair Centers and Consolidated™ Green Tag™ Centers help you easily identify and service the valves that need it the most, making turnarounds and planned maintenance easier.

Increase Efficiency

Our legacy of innovating control valve and pressure relief valve technology provides the right solutions to ensure installed valves are configured and sized to reduce operational costs, maximize process efficiency and keep critical processes running smoothly.

Improve Reliability

Our engineers work closely with our customers and regulatory agencies to ensure that our valves are designed for compliance and each specific installation, maintaining safe and reliable performance over the installed lifecycle with reduced maintenance.

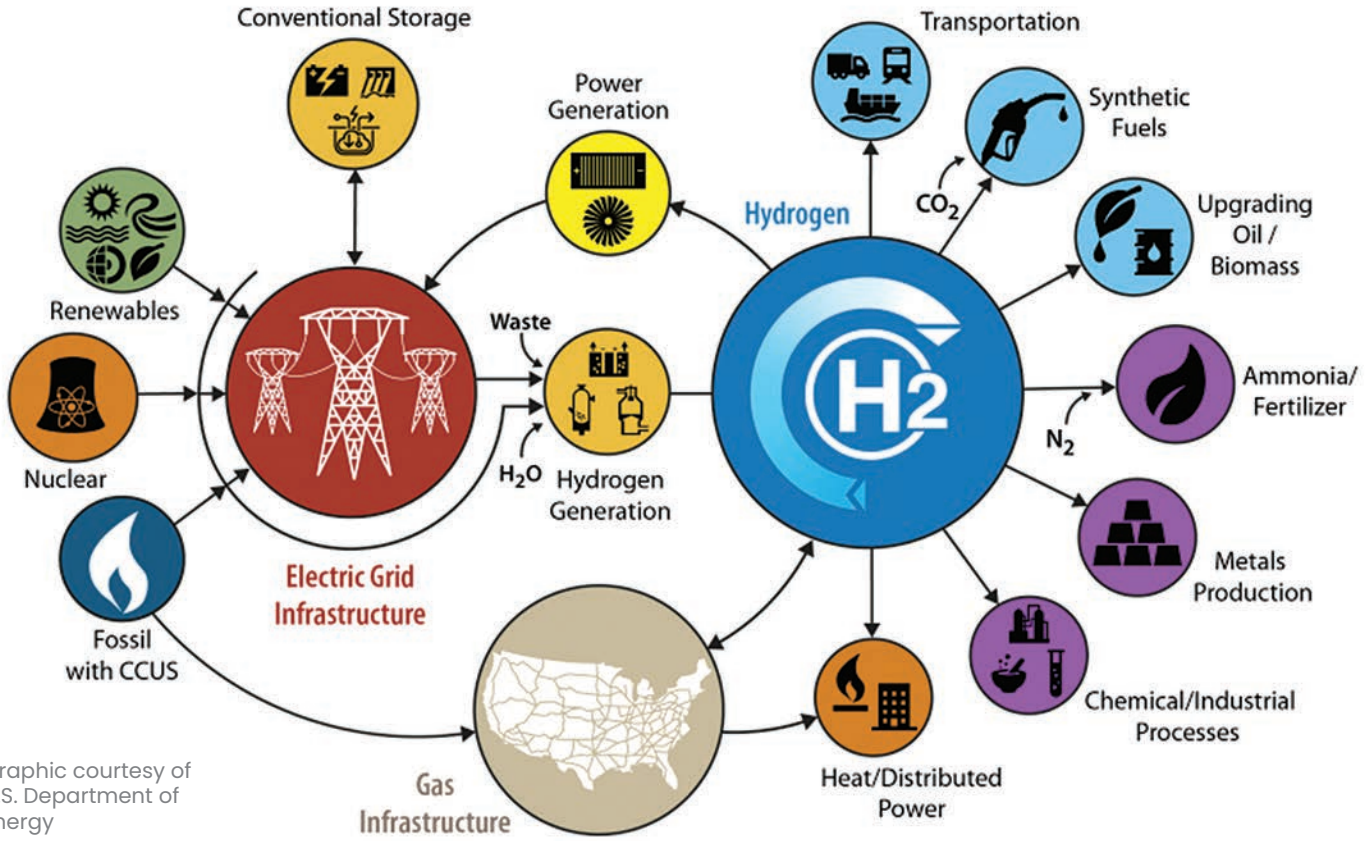
Reduce Emissions

Fugitive emissions not only cost money but can be harmful to the environment. With an ever-growing number of companies committed to achieving carbon neutral status in the next decade, best-in-class leak tightness and superior valve technology are required in every process design.

Baker Hughes has the right valve for your hydrogen applications

Baker Hughes has been a leading supplier of valves for hydrogen production for decades, as part of traditional brown, gray, and blue hydrogen production through traditional hydrocarbon refining processes. Today our range of products expands through each of these processes and covers most of the necessary control and safety valves to prevent from hydrogen embrittlement (or "blistering") in service, and our valves are extensively performance tested to handle extremely high cycling of 100k cycles or more per year.

Hydrogen Ecosystem



Graphic courtesy of U.S. Department of Energy

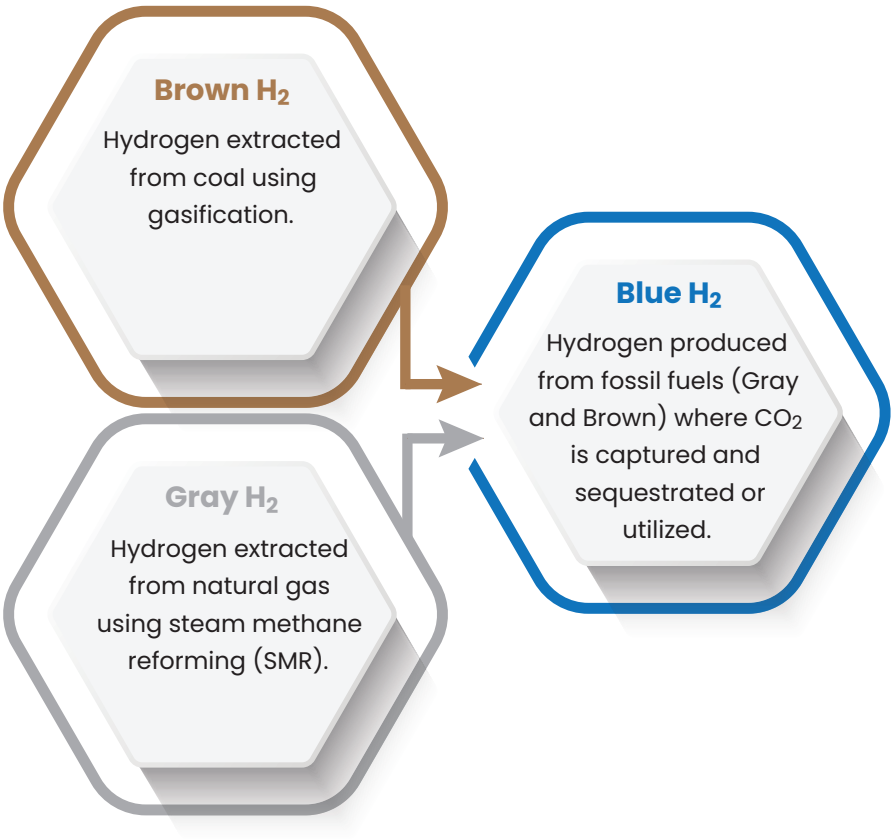
With most of the world's countries and manufacturers committing to 'net-zero' emissions within the coming decades, engineers are faced with new challenges to create technology solutions for customers, as well as design and maintain optimized processes that stay operational longer, contain costs, and reduce or eliminate emission.

Today, hydrogen is emerging as a global solution for clean fuel, as it can be transported locally or globally as liquid hydrogen, e-FUEL or ammonia.

Hydrogen Production

Hydrogen has long been a fuel source and byproduct of fossil fuel refining processes, and a core segment of the market supported with Masoneilan and Consolidated valves for decades. As more industries turn to this element as a critical green fuel source, the need for efficient production, transportation and delivery is greater than ever before.

Hydrogen has many forms of production : Steam Methane Reforming (SMR), gasification (coal) and electrolysis (water). Regardless of the production technology, Baker Hughes has control and safety valves that provide optimized flow control as well as a safe environment for personnel.

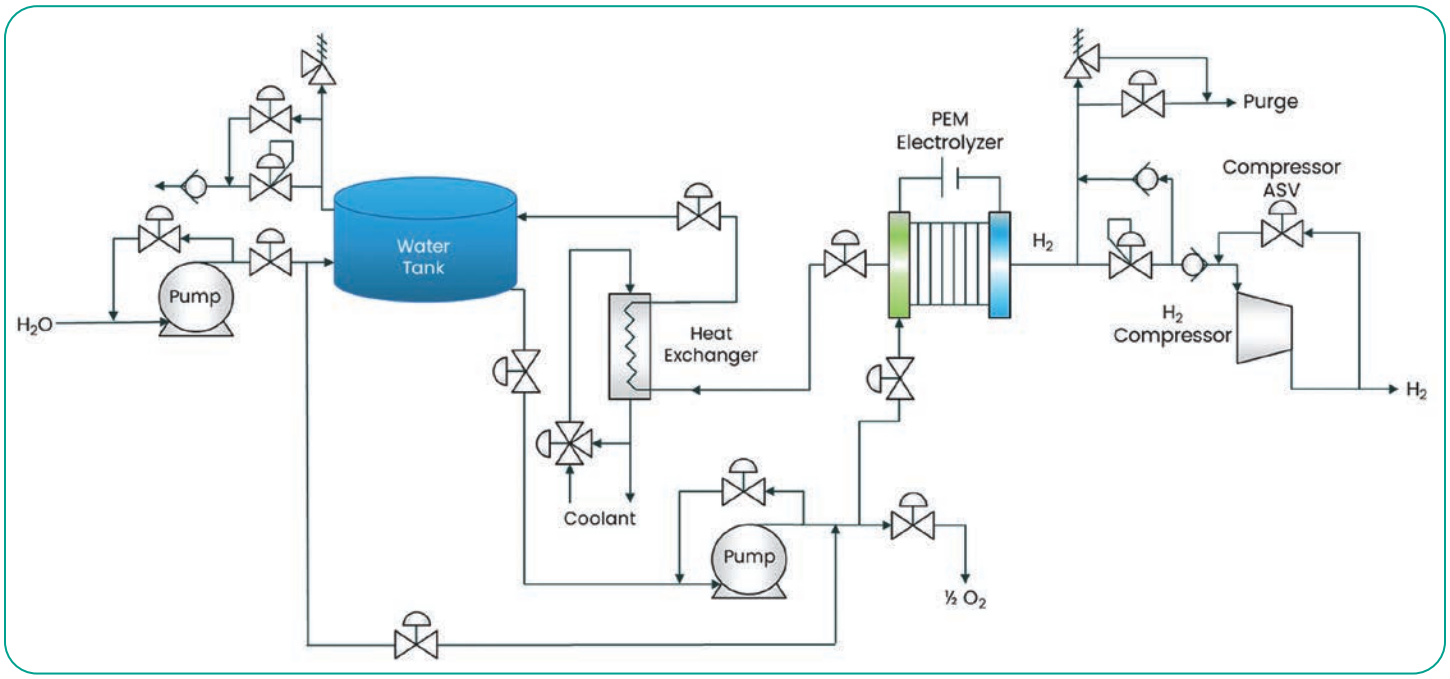


Hydrogen is poised to play a significant role in our clean energy future, however, that will require a shift from gray (hydrocarbon refining) and brown (coal gasification) production to green/blue/pink/turquoise hydrogen and the related technology system changes.

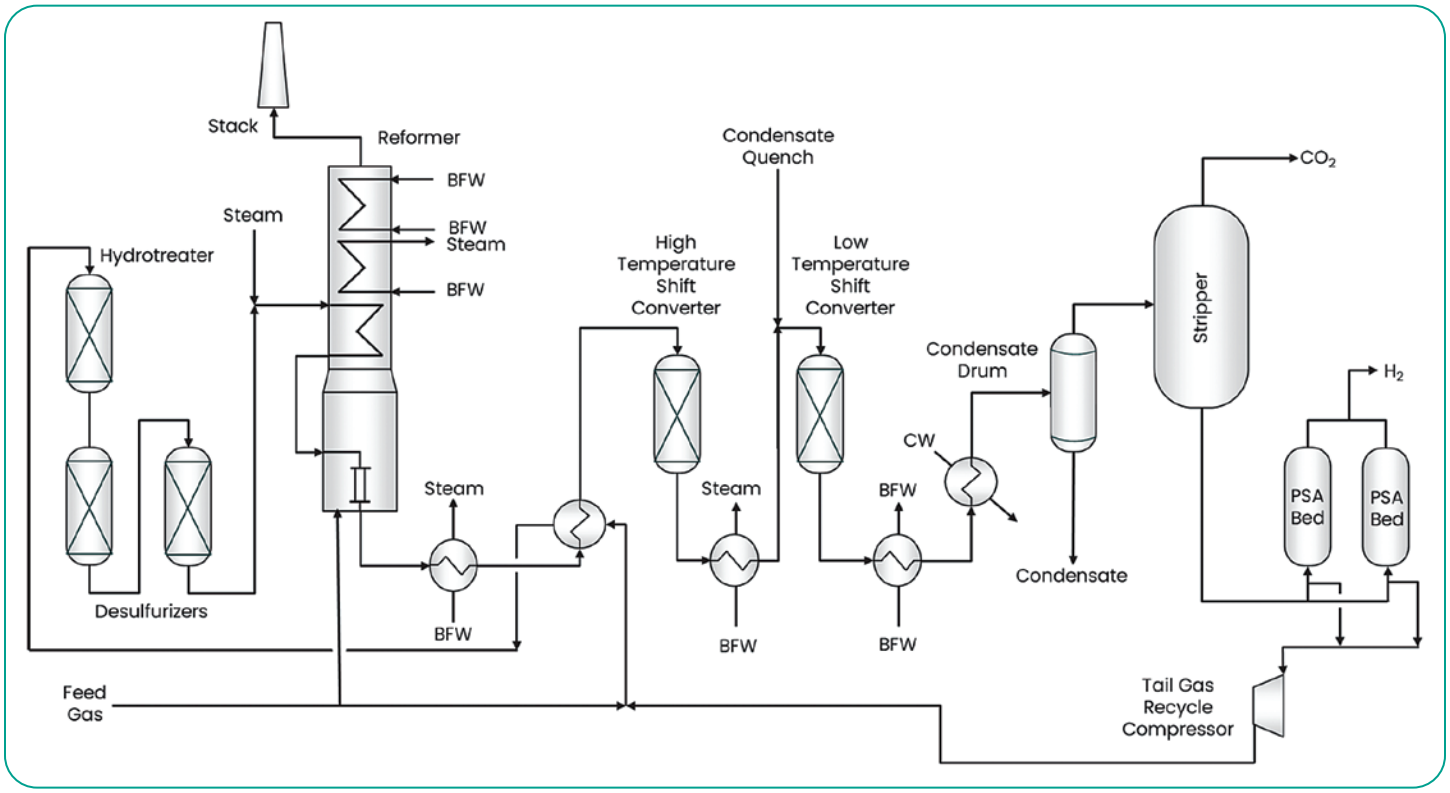
The expansion of renewable energy sources as well as the ability to integrate renewables into developed industry, energy generation, and mobility infrastructures using decarbonized or green hydrogen will help to decarbonize the world.

Hydrogen Production

Green hydrogen is a clean energy source that only emits water vapor and is considered a 'ZERO" emission hydrogen process.



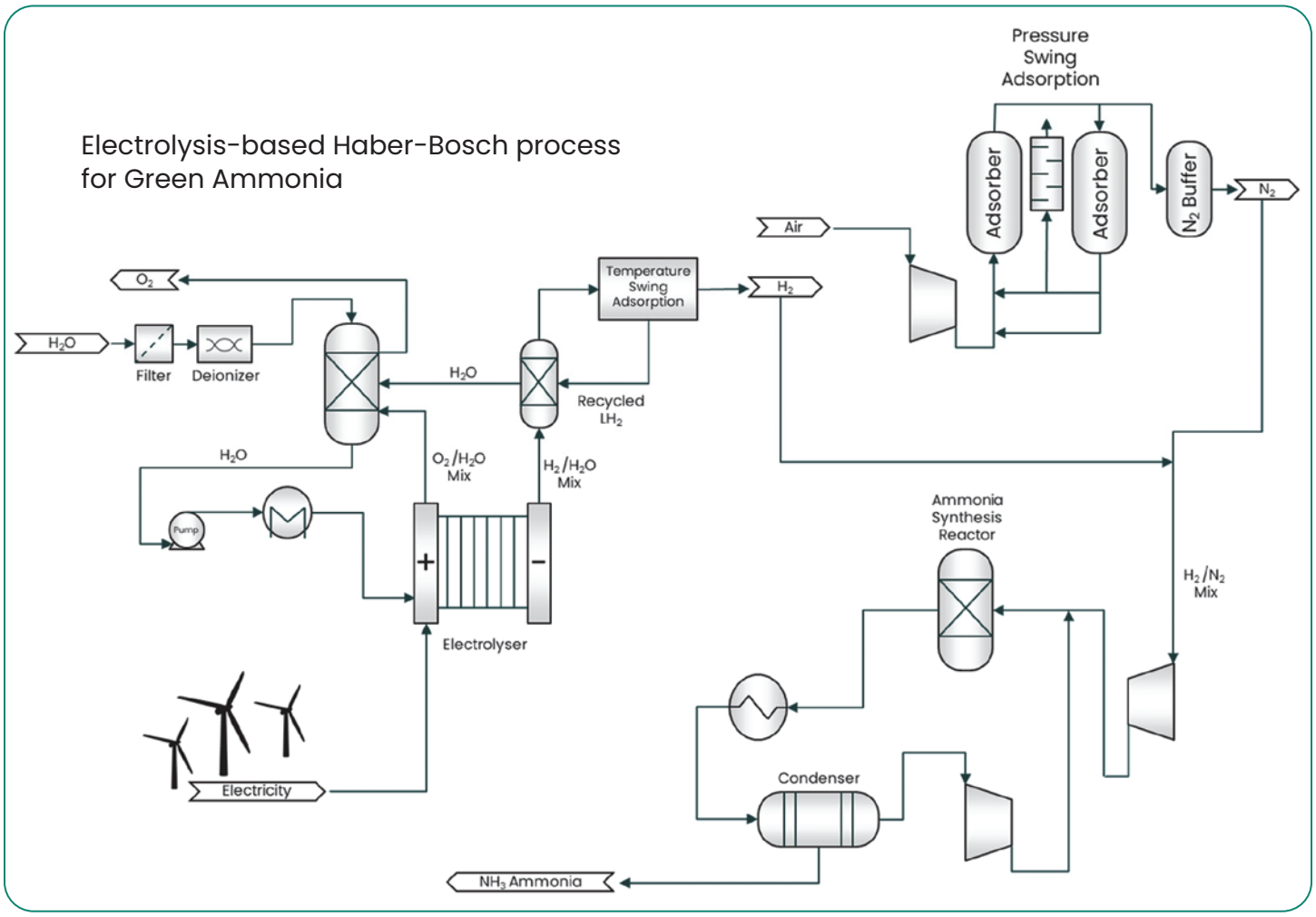
About 75% of blue hydrogen is derived from natural gas through the steam methane reforming (SMR) process as shown below. SMR mixes natural gas with very hot steam, in the presence of a catalyst, where a chemical reaction creates hydrogen, along with carbon, which can then captured for use or storage to maintain the "blue" clean energy requirements.



Ammonia Production

Corollary to hydrogen production, the introduction of nitrogen through the Haber-Bosh process creates Ammonia (NH3) as a widely used green product. Ammonia is produced in vast quantities worldwide mainly for use as an agricultural fertilizer, but these processes use natural gas or other fossil fuels to provide both the hydrogen feedstock and the energy to power the synthesis process. As a result, ammonia production by these methods releases CO_2 emissions. Similar to hydrogen, ammonia has no carbon emissions at its point of use, and as an added benefit it is a product that is easier to transport and safer overall to handle.

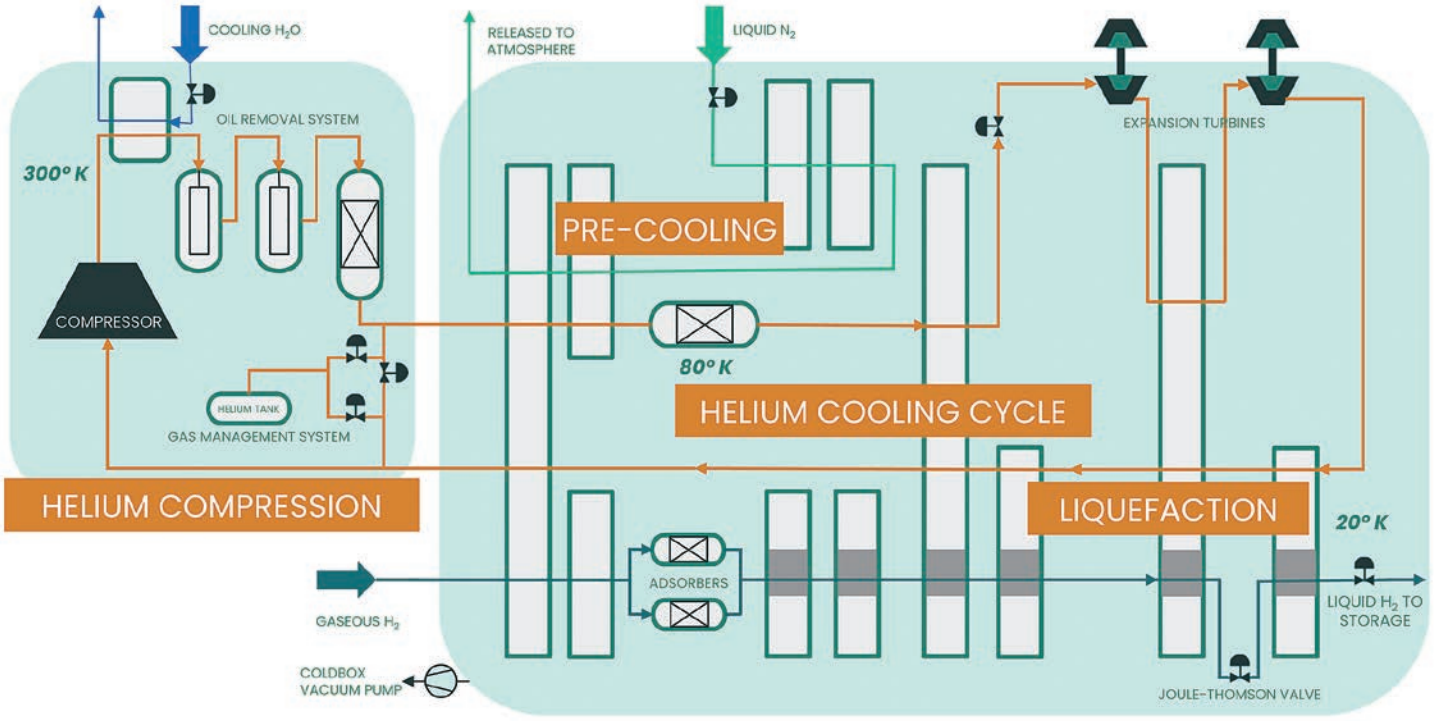
Green ammonia is produced using renewable energy and water



Hydrogen Liquefaction

Hydrogen liquefaction is one of the most significant, and challenging, processes in the entire ecosystem. Storing hydrogen as a liquid for compact transportation requires cryogenic temperature reduction to below -253°C (-423°F). The integrated system for H2 liquefaction consists of three main process stages: cryogenic pre-cooling, cryogenic cooling and liquefying.

Common Hydrogen Liquefaction Process

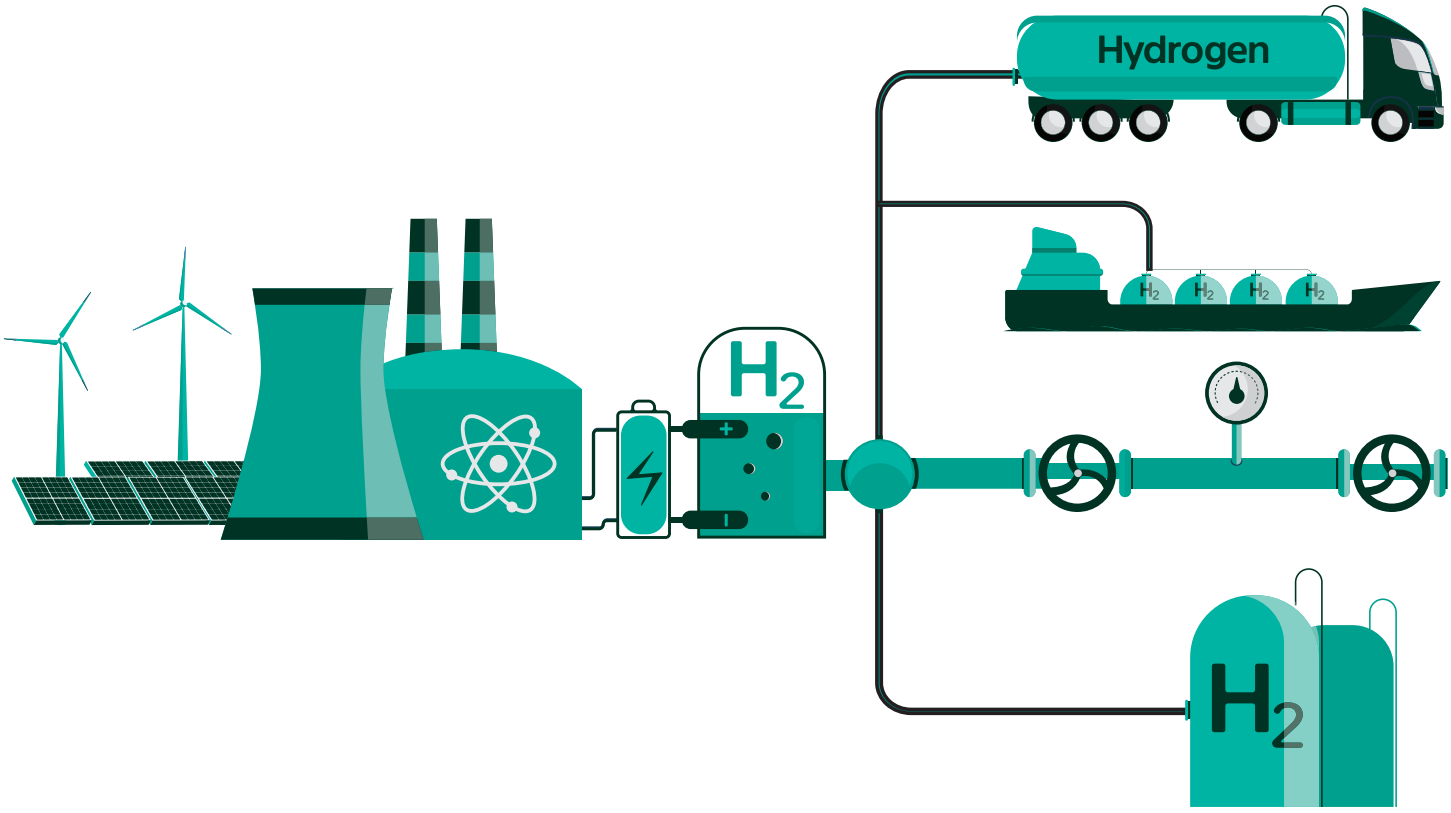


For over 40 years, Baker Hughes has supplied cryogenic valves for liquid hydrogen service. Today we continue our legacy of innovation by developing new valve technologies for a rapidly evolving industry. Our expanded portfolio maintains the latest ISO standards with a full suite of cryogenic valves for service in liquefied natural gas (LNG), liquefied oxygen (rocket engines), and many more sub-zero temperature applications under high pressure.

Designed for safety, all valves are tested in our global cryogenic test facilities which all include digitally automated, ballistic test stands that are remotely operated for ultimate safety standards with repeatable control and shutoff performance under pressure.

Hydrogen Transportation

Safety is by far the highest priority when designing products for hydrogen transportation. Hydrogen can be either pressurized as a compressed gas or liquefied under cryogenic process. It's then transported from the point of production to the point of use via pipeline or over the road in cryogenic liquid tanker trucks or gaseous tube trailers. Hydrogen requires only one tenth of the energy necessary to ignite natural gas, is harder for fire suppression, and releases about 400% more energy in an explosion.



Baker Hughes pipeline products, such as Masoneilan™ triple offset valves, Becker™ low noise ball valves, and Mooney™ Slam-Shut systems, are each designed with materials specific for hydrogen service. Many transportation pipelines move a mixture of fluids, where the hydrogen percentage can exceed limits of commonly used elastomers. Under pressure, the hydrogen atom can permeate through elastomer materials, and upon release of the pressure can rapidly escape and cause explosion decompression (ED). For these applications, ED resistant materials are required to prevent a catastrophic failure.

Typical Flow Control Solutions for Hydrogen Systems

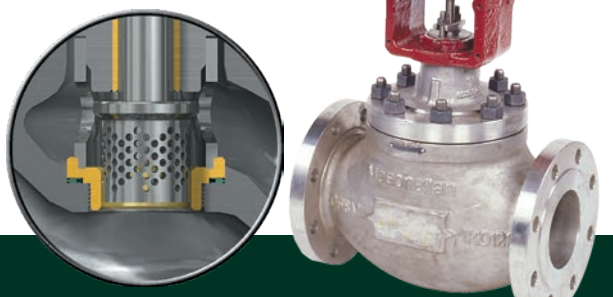
Hydrogen Production	Steam Methane Reforming	Feed Gas & Fuel Gas Control, High rangeability	Masoneilan 21000, 41005 Multi-stage Lo-dB
			Masoneilan 33000 Triple Offset
		Antisurge & Gas to Flare, Fast Response, High rangeability	Masoneilan 41005 Multi-stage Lo-dB
			Masoneilan 49000 Series V-Log™
		Liquid High Pressure Pump Recirculation, Feedwater Control	Masoneilan 41005 Multi-stage Anti-cav
			Masoneilan 18400/78400 LincolnLog™
		Boiler safety valves; high pressure steam Economizer; multiphase	Consolidated SV - 1700 Maxiflow™, 2700, 1811, 1511
			Consolidated 2900-40 POSRV
		Reformer/reactor overpressure protection	Consolidated SRV - 1900 DM, 1900, 19000, 1982
			Consolidated POSRV - 2900 Gen II , 3900
	Purification (Pressure Swing Adsorption)	Feed Gas Control & On/Off, Tight shutoff, high cycling reliability	Masoneilan 21000, 41005 Multi-stage Lo-dB
			Masoneilan 33000 Triple Offset
		Purge supply control	Masoneilan 35002 Camflex™
		Repressurization control, high pressure	Masoneilan 21000, 41005 Multi-stage Lo-dB
		Absorber overpressure protection	Consolidated SRV - 19000, 1982
	Coal Gasification	Black water letdown, high velocity entrained solids	Masoneilan 73000 Series Sweep Angle
		High Pressure Oxygen Control & Isolation	Masoneilan 33000 Triple Offset, 21000 Single Stage
		Air separation, compressor antisurge high noise & vibration	Masoneilan 41005 Multi-stage Lo-dB
			Masoneilan 49000 Series V-Log
		Rich Amine letdown, high pressure, corrosive fluid	Masoneilan 18400/78400 LincolnLog
		Vessel overpressure protection; gasifier/reactor, separator, scrubber	Consolidated SRV - 1900 DM, 1900, 19000, 1982
			Consolidated POSRV - 2900 Gen II , 3900
	Carbon Capture	Absorbers, pump recirculation, tight shutoff	Masoneilan 35002 Camflex, 21000 Single Stage
		Heat Exchange, low pressure drop, 3-way valve	Masoneilan 10000 series, 80000 3-way valve
		Stripping/Washing, cooling water flow control	Masoneilan 35002 Camflex, 21000 Single Stage
	Water Electrolysis	Water flow control, pump recirculation	Masoneilan 35002 Camflex, 21000 Single Stage
		Flow control & Isolation	Masoneilan 35002 Camflex, 33000 Triple Offset
		Reactor & evaporator	Masoneilan 21000, 41005 Single Stage
		Separator vessels; overpressure protection	Consolidated SRV - 1900 DM, 1900, 19000, 1982
			Consolidated POSRV - 2900 Gen II, 3900
		Fuel tank, exhaust tank pressure relief	Consolidated SRV - 1900 DM, 1900, 19000, 1982
			Consolidated POSRV - 2900 Gen II, 3900
Ammonia Production	Ammonia Inlet FEED	H2 / N2 compressor anti-surge valves	MN 41005, Multiple stage Lo-dB
			MN 49000 / 72005 with V-LOG trim
	Ammonia Steam Production	Steam pressure reducing stations	MN 41005, Multiple stage Lo-dB
			MN 84000 Steamform
		Boiler Feed water / feed water pump recirculation	MN 41005 Multistage Anti-cav
			MN 41005 Multistage VRT
			MN 18400 / 78400 LincolnLog
		Steam vent	MN 41005, Multiple stage Lo-dB
	Ammonia Process	Liquid ammonia letdown	MN 18400 / 78400 LincolnLog

Typical Flow Control Solutions for Hydrogen Systems

Liquefaction	Gas Compression	Antisurge, Fast Response, Feed gas control	Masoneilan 41005 Multi-stage Lo-dB
			Masoneilan 49000, 72000 Series V-Log
	Pre-cooling & Liquefaction	Joule-Thompson, multistage letdown, Cryogenic	Masoneilan 41005 Multi-stage Lo-dB
			Masoneilan 49000 Series V-Log
		Liquid H2 Cryogenic Storage	Masoneilan 21000, 41005 Single Stage
			Masoneilan 33000 Triple Offset
		Liquid H2 Cryogenic Pump Recirculation	Masoneilan 41005 Single Stage
			Masoneilan 18400/78400 LincolnLog
		Pressure relief; multi-media (liquid/gas), 2-phase fluid, cryogenic temperature	Consolidated SRV - 1900 DM, 1900, 19000, 1982
			Consolidated 2900 Gen II POSRV
Transportation Storage and Distribution	Pipeline	Pressure Regulation, Low noise control, over/under pressure protection	Becker T-Ball, Multistage
			Mooney Flowgrid, Flowgrid Slam Shut, FlowMax
		Thermal expansion relief	Consolidated SRV - 19000, 1982
	Compression	Antisurge, Fast Response	Becker T-Ball, Multistage
			Masoneilan 41005 Multi-stage Lo-dB
		Compressor excessive pressure protection	Consolidated SRV - 1900, 19000, 1982
	Gas Storage	Bi-directional flow (injection, withdrawal), Degassing/icing	Masoneilan 41005 Multi-stage Lo-dB
			Masoneilan 49000 Series V-Log
			Becker T-Ball, Multistage
		Large vessel pressure relief; liquid cryogenic temperature	Consolidated SRV - 1900 DM, 1900, 19000, 1982
			Consolidated 2900 Gen II POSRV

Masoneilan™ Globe Valves for Hydrogen Systems

Masoneilan offers a full range of control solutions, designed for the size, pressure reduction, and flow capacity required for each application.



21000 Series

The Masoneilan 21000 Series heavy top-guided globe valve can be installed for a wide range of general service applications. The 21000 Series product line features a single-ported unbalanced design configuration, which permits numerous trim, actuation, and instrumentation solutions.

41005 Series

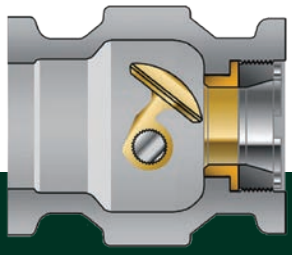
The Masoneilan 41005 Series heavy duty severe service valve features balanced trim with multistage pressure reduction, ideal for a higher range of demanding operating conditions. The 41005 valve includes low noise/anti-caviation trim for high pressure reduction, large temperature variation materials for cryogenic service, and a lower balancing seal ring with large capacity flow to support compressor anti-surge applications up to 30” in size.

21000 Series & 41005 Series Features:

- ISO 15848-1 Certified, Environmental Low-Emission Packing (<15 ppm)
- Low Noise & Anti-Cavitation Multistage Trim
- Lower Balancing Seal for Small Movement, Fast Response Compressor Anti-Surge
- Cryogenic Configuration
- Tight Shutoff Design
- Light Duty and Reduced Capacity Options
- Advanced Diagnostics and Digital Positioning Control

Masoneilan™ Rotary Valves for Hydrogen Systems

Masoneilan rotary control valves offer a high capacity, tight shutoff solution for many key applications.



Camflex 35002 Series

The Camflex Rotary Globe Control Valve combines the best features of a traditional globe valve in a rotary platform. The eccentric contoured plug provides true globe valve seating and control performance with the enhanced benefits provided by the inherent force amplification resulting in a smaller, more responsive actuator package. The standard extended bonnet allows application over a wide temperature range.

- Entirely Eliminates Body-to-Bonnet Leakage
- Industry Leading, Best-in-Class ISO 15848-1 Certified Low Emissions (<1 ppm)
- Cryogenic Extension Available

33000 Series Triple Offset Valve

The 33000 Series triple offset valve provides zero leakage performance for extreme pressure and temperature applications, providing a safe environment. Enhanced features of the 33000 Series make it an excellent solution for hydrogen service:

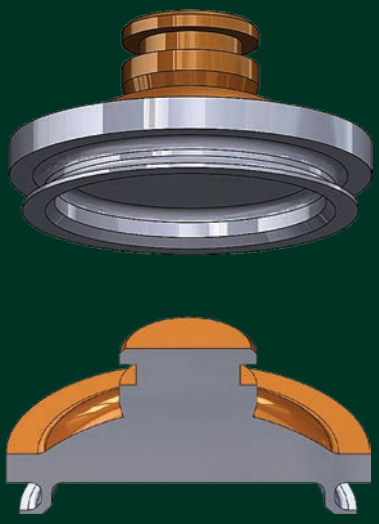
- Self-centering disc without pins or keyways
- Low torque with square actuator connection
- Control accuracy with the SVI™3 smart digital positioner

Consolidated™ Safety Relief Valves for Hydrogen Systems

Consolidated combines safety, stability, and emissions reduction for many hydrogen applications.

1900 Series Dual Media (DM)

The patented innovation of the Dual Media trim design makes it the first and only spring-loaded safety relief valve (SRV) in the industry that is “dual certified”, as defined by API Standard 520 Part 1 – Sizing and Selection, 10th Edition. The 1900 DM trim is engineered to perform on both liquid and/or gas media with exceptional blowdown performance and is dual certified to meet multi-media (liquid and gas) capacity stamping per ASME BPVC Code Case 2787. The 1900 DM trim is ideal for any liquid or gas application, two-phase liquid and gas, flashing or multiple relief case scenarios.



Patented Cryodisc Technology

Seat leakage in cryogenic applications, such as liquefaction, is a common problem due to dramatic thermal stresses in the materials of seating components.

Our Cryodisc technology uses the thermal stresses to deflect the patented disc thermolip downward to create a uniform contact pressure seat resulting in enhanced seat tightness. This unique seat design is available for both our 1900 Series spring-loaded and 2900 Series pilot-operated SRVs.

Consolidated™ Safety Relief Valves for Hydrogen Systems

Consolidated offers zero leakage and reliable pilot valve solutions for optimizing even the most demanding hydrogen applications.

2900 Series Gen II

The 2900 Series Gen II is a pilot-operated SRV offering a unique full-nozzle design for protecting the valve body during severe service conditions.

3900 Series

The 3900 Series is a modular pilot-operated SRV featuring a conventional semi-nozzle design for easy access and maintenance of the main valve seat sealing area.

Triple Media (TM) Certification

The TM Series, available for both the 2900 Series and 3900 Series, meets agency certification requirements for multiple media for multiple media capacity stamping per ASME B & PVC Code Case 2787, validating valve performance on any service without changes to set pressure or part modifications. The TM Series provides exceptional set pressure performance, stable opening and closing, and exceptional blowdown performance ensuring the system is efficiently protected from an overpressure event with air, gas, liquid, steam, or a two-phase mixture as the relieving media.

"True Zero Leakage Pilot"

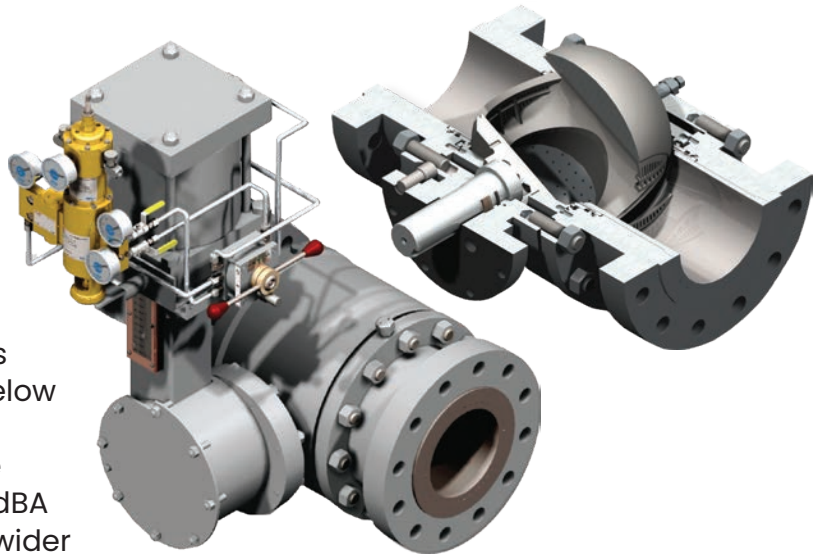
Both valve series use the "True Zero Leakage" modulating pilot that provides a modernized overpressure protection solution for reducing carbon footprint, emissions, and product loss.

There is no need to shutdown with the Field Test Connection accessory that comes standard with every Consolidated pilot.

Becker™ & Mooney™ Pipeline and Transmission Valves for Hydrogen Applications

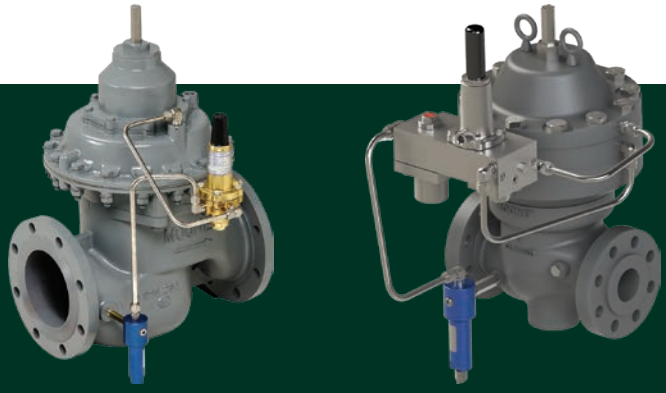
Becker T-Ball

The Becker T-Ball is a rotary control valve designed for gas and liquid applications, including gas with hydrogen concentrations up to 20%. Becker valves and instrumentation are ideal for demanding applications that require aggressive noise attenuation, high pressure differentials, large mass flow volumes and extreme precision. We offer above and below grade valve and actuator designs to satisfy application and site requirements. Multi-stage trim designs provide noise reduction up to 25 dBA and Turndown Ratios of up to 300:1 to cover a wider range of service conditions.



Mooney Flowgrid™

The Mooney Flowgrid Regulator is an easy-to-maintain, zero emission self-contained pilot regulator system for almost any gas or liquid, including gas applications with hydrogen concentrations up to 20%. The ability to control pressure and flow increases accuracy, responsiveness and stability while decreasing noise levels, maintenance and energy costs. Providing top entry access to all components, the Mooney Flowgrid regulator reduces expense of maintenance, while allowing for more efficient and reliable production.



Mooney FlowMax™ & FlowMax™ HP

Mooney FlowMax Regulators are fail-closed top entry regulators for gas applications, also with hydrogen concentration limits up to 20%.

The top-entry design provides easy maintenance combined with zero emissions. Dual path control and low full open differential pressure increase accuracy and control range. Lo-dB noise reduction trim options provide up to 30 dB reduction for high pressure drop and high mass flow applications. The positive fail-closed design increases system safety and complements fail-open regulators in redundant system design.

Masoneilan™ SVI™ Digital Control Valve Positioner

Control and monitor your critical valve assets with the proven reliability of the SVI platform and new Valve Diagnostics.

SVI3 Digital Valve Positioner

The SVI is a user-friendly digital valve positioner for pneumatic control valves. Utilizing advanced control and diagnostic algorithms, along with field proven, non-contact position sensing technology, the SVI delivers accurate, responsive, and reliable positioning performance.

Continuous Health Monitoring

Improve plant efficiency and process uptime with continuously calculated diagnostics which monitor the health of the valve and process.

Plan turnarounds and prioritize repair events via data driven decisions utilizing one year of on-device diagnostic storage.

Simple, Modular Platform

Automated, self-calibration routines and universal mounting system provide effortless setup and commissioning across any linear or rotary control valve.

Performance & Reliability

Built upon 20+ years of field proven technologies with billions of operating hours, the SVI is trusted on the most critical applications.

Ready to Serve, Anywhere!

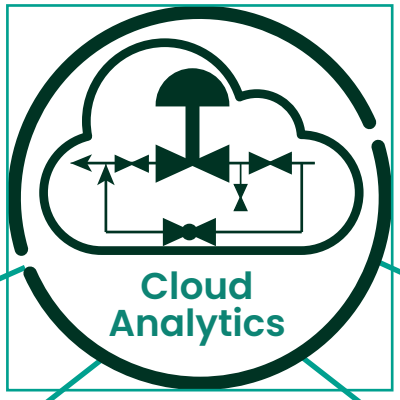
Designed with corrosion resistant materials, and universally certified to global hazardous area standards. Ready to serve with explosion proof rating for the presence of hydrogen.

Valve Lifecycle Management Solutions

Driving Outcomes

The industries we serve are evolving to pursue new frontiers with an increased focus on corporate social responsibility. Reducing emissions and ensuring safety are non-negotiables in the modern economy, while pressure to unlock new growth and improve margins continues to increase. As these industries seek to modernize and future-proof their operations accordingly, now more than ever, these operators are looking for more than a valve supplier. They are looking for a partner going into the future who can deliver comprehensive Valve Lifecycle Solutions enabling them to deliver on their commitments and to address their toughest operational challenges.

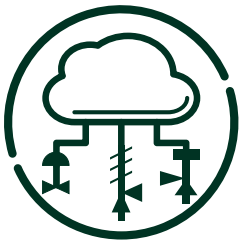
Valve Lifecycle Management



VLM Services

- Asset Management
- Calibration & Tuning
- Monitoring & Diagnostics
- Turnaround Management
- Product Upgrades

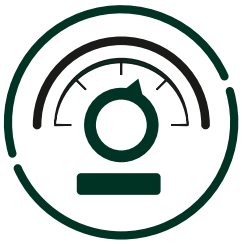
Product & Application	Maintenance & Repair	Discrete Monitoring	Continuous Monitoring
Factory Tests	Service Intervals	Digital Positioner Calibration	Distributed Sensors
Quality Data	Repair History	Digital Positioner Diagnostics	Supply Pressure
ERP Production Data	Critical Dimension Measurements	DTM Calibration & Tuning	Temperature
Product Sizing & Configuration	Visual Inspection	EVT Pro PRV Functional Test	Friction
Product Design	As Received vs. Shipped	ValScope PRO Control Valve Test	RMS Error
			Overshoot



ValvKeep

Valve Asset Management software application to track and manage all valve assets throughout the entire lifecycle

- Valve Repair Quality System
- Brand Agnostic
- Service & Repair History
- Turnaround Planning
- Documents & Reports
- On-Demand Photos & Data



ValvAware

Online valve health monitoring service enabling condition-based monitoring in real process conditions without production interruption.

- Read Only Secure Operations
- Brand Agnostic
- Reports Turn Data into Action
- 16 KPI & Performance Trending
- Compatible with OPC & DCS

ValVue3

Device Type Manager (DTM) application performs the configuration, calibration, and performance testing of your Masoneilan digital devices.

- One Click Calibration Auto-Tunes Positioner to any Control Valve
- Run Remote Diagnostics
- Integrate with AMS, PRM, & FDM

ValScope

In-line or offline control valve diagnostics and troubleshooting device to evaluate & optimize control valve performance and loop efficiency.

- Complete Control Valve Signature within Minutes
- Graphical Interface to Visualize
- Portable for in-line or in-house uses
- Rugged Durable Construction

EVT PRO

In-situ pressure relief valve portable testing device to confirm valve set pressure in process and under normal operating conditions.

- Ensure PRV Set Pressure is Calibrated
- Portable for in-situ use
- Perform Test Without Shut-Down
- Rugged Durable Construction

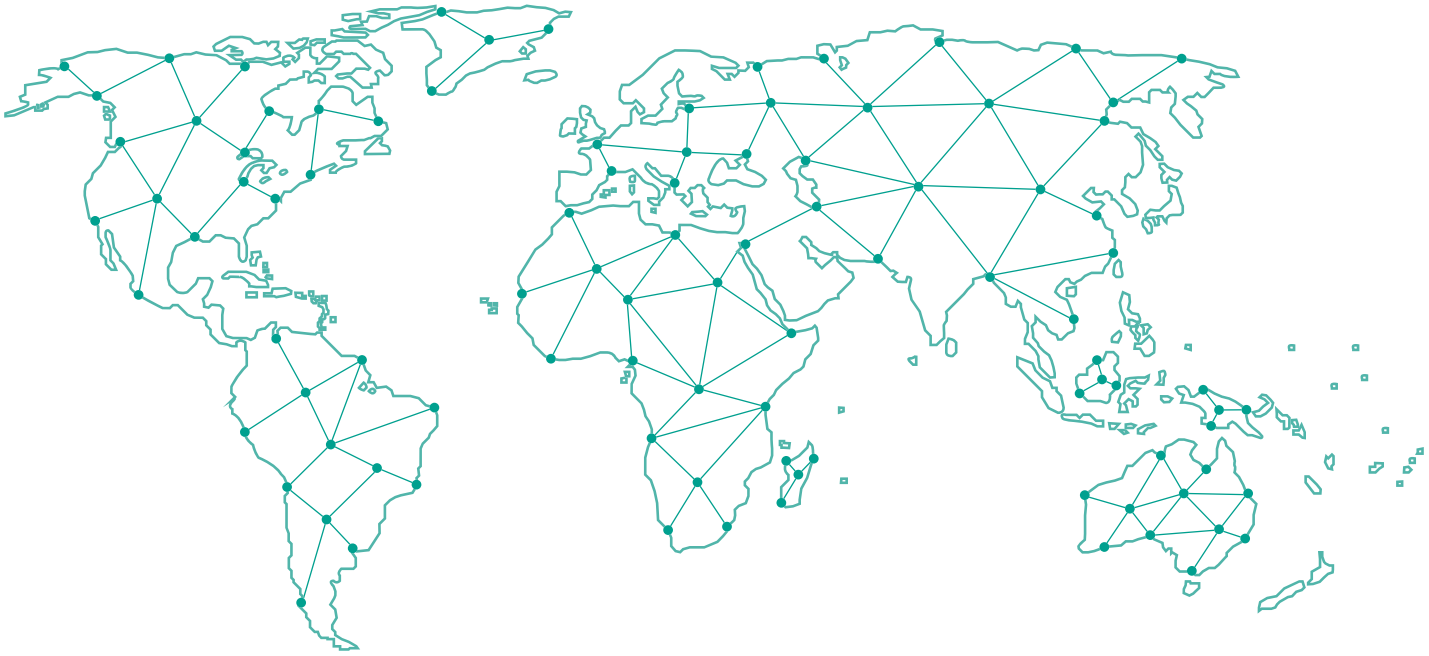
ValvStream

Valve sizing & selection tool for Pressure Relief Valves and Control Valves to guide the proper selection of the right valve for the right application.

- Guided Valve Selection
- Sizing & Calculation Sheets
- Drawing
- Bill of Materials
- Specify Special Certs & Tests

Find the nearest local Channel Partner in your area:

valves.bakerhughes.com/contact-us



Tech Field Support & Warranty:

Phone: +1-866-827-5378
valvesupport@bakerhughes.com

valves.bakerhughes.com

Baker Hughes

BHMN-Hydrogen-BR-34612B-0123 01/2023

bakerhughes.com