



# HYDROGEN ECONOMY

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A Complete Flow Control Portfolio to Enable Your Energy Transition Initiatives

# HYDROGEN: EMPOWERING ENERGY TRANSITION

The need for low-carbon energy fuels has never been greater. A powerful enabler of energy transition, hydrogen ...

- Is clean, sustainable and flexible
- Can be produced from renewable electricity and from carbon-abated fossil fuels
- Is a versatile, safe energy carrier that can be used as fuel for transportation and power and as feedstock for industry
- Produces zero emissions at point of use



# SINGLE SOURCE FOR HYDROGEN SPECIALISTS

Flowserve offers a wide range of products for the flow control industry, but we are more than an equipment supplier.

## We offer unique advantages to help you achieve your energy transition objectives:

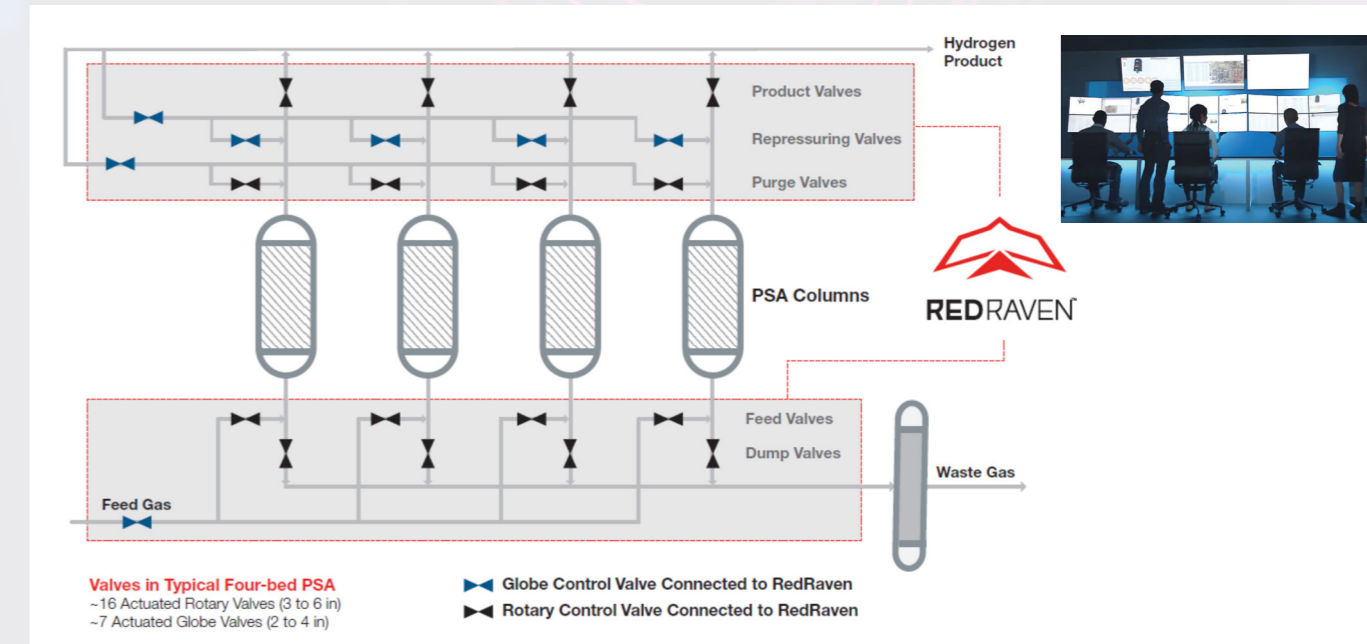
- The most complete portfolio of flow control equipment working as a system to optimize hydrogen processes
- Expertise in assessment, engineering and implementation to enhance process efficiency and cost-effectiveness
- A single point of contact for
  - project planning with engineering, procurement and construction (EPC) contractors and company project managers
  - commissioning and operations with plant managers and technicians
- Unparalleled service and technical expertise backed by a global network of quick response centers (QRCs)

# PREDICTIVE ANALYTICS AND LIFECYCLE SERVICES

The ability to detect, diagnose and quickly respond to equipment and system issues

The hydrogen energy industry needs more than engineered-to-order systems. In addition to the most complete and flexible flow control solutions portfolio, Flowserve offers RedRaven, our end-to-end IoT solution that provides remote sensing, condition monitoring and predictive analytics to identify and address equipment problems before they cause costly downtimes.

Our team of service, support and monitoring center specialists is ready to serve you with equipment insights, alert response best practices and process recommendations.

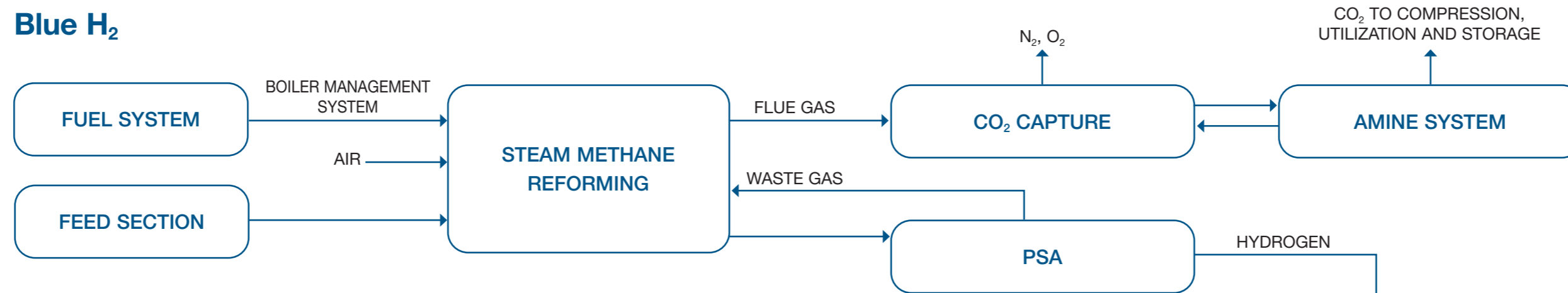


Pressure swing adsorption (PSA) is vulnerable to production constraints when control valves fail or deviate from expected behavior. RedRaven provides insights on equipment health and allows plant operators to proactively identify and address issues before they cause downtime and operational disruptions. Its remote monitoring capabilities coupled with experienced Flowserve support facilitates quick resolution of identified problems.

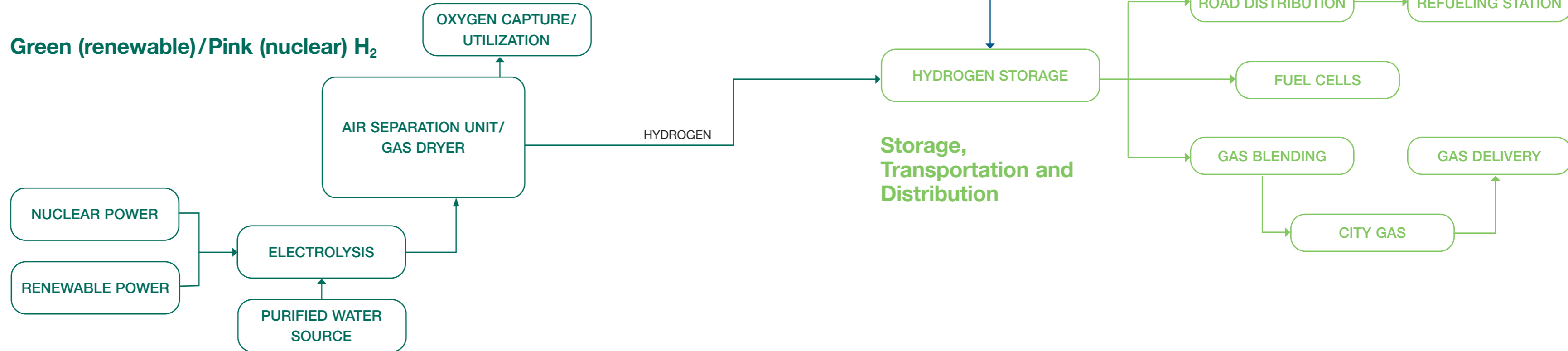
On a typical large-scale hydrogen plant, even a 1% increase in PSA unit availability through reduced downtime can lead to a significant positive impact on throughput and profits. The benefit can be even higher by preventing the effects of hydrogen outage on downstream units.

# PROVEN SOLUTIONS THROUGHOUT THE HYDROGEN VALUE CHAIN

## Blue H<sub>2</sub>

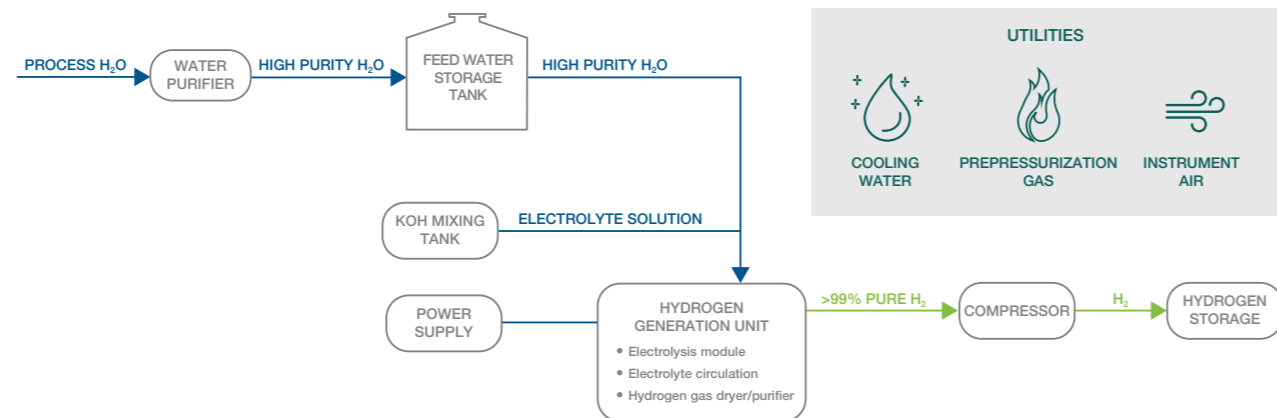


## Green (renewable)/Pink (nuclear) H<sub>2</sub>



# GREEN HYDROGEN ELECTROLYSIS

Powered by solar, wind or other renewable energy sources, this process delivers green hydrogen without fossil fuels.



## Key process areas and product considerations

Green hydrogen electrolysis is produced from one of four technologies: alkaline, polymer electrolyte membrane (PEM), anion exchange membrane (AEM) and solid oxide (SOEC).

### Electrolyte Circulation

A critical step in the alkaline electrolysis process is the mixing and circulation of a liquid electrolyte, typically potassium hydroxide, with water across a cathode and anode to induce a reaction under voltage.

### Air Separation

Among the different electrolysis technologies available, gas output may not end up as a pure gas stream. Air separation and purification of the hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>) gas may occur through pressure swing adsorption (PSA), where adsorbent beds operated with control valves operate cyclically to clean the gas stream.

## Isolation Valves



Feed control, tight shutoff and bed isolation across pressure swing adsorption (PSA) are critical criteria for isolation valves in the production of green hydrogen.

**Argus** FK76, FK79 and others

**Worcester** Series 51/52, 819/829 and others

## Control Valves



Our Valtek products offer robust high cycles and tight shutoff for PSA operation, fast stroking anti-surge for compression and deep cryogenic for separation and storage.

**Valtek Linear** MK1, MK100SC, FlowTop

**Valtek Rotary** MaxFlo 4 Valdisk

## Automation

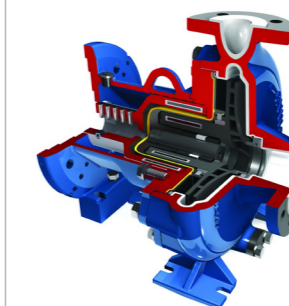


Flowserve's Logix positioners deliver best-in-class calibration, and when partnered with Valtek or Limitorque actuators, deliver smooth and reliable operation.

**Logix** 3800

**Limitorque** LPL

## Pumps



Leak- and maintenance-free designs are critical for circulation and cooling pumps in green hydrogen production. Low total cost of ownership helps manage costs.

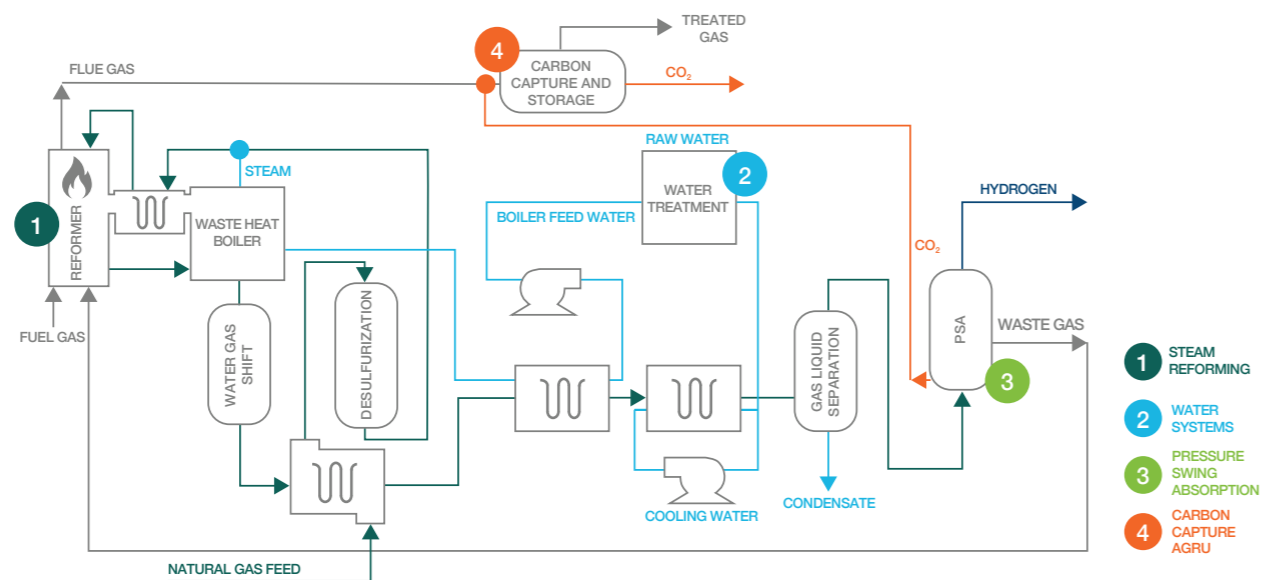
**INNOMAG** TB-Mag

**Durco** Mark 3

**SIHI** CBTA, ZLND

# BLUE HYDROGEN PRODUCTION

Blue hydrogen production adds carbon capture, utilization and storage to steam methane reforming



## Key process areas and product considerations

### Steam Methane Reforming

Typically natural gas (methane) serves as the feed. It is preheated in the reformer and passes through hydro-desulphurization beds to remove hydrogen sulfide (H<sub>2</sub>S). Inside the reformer, an endothermic steam methane reforming reaction occurs in the presence of a catalyst, producing hydrogen and carbon monoxide (CO). In the subsequent water gas shift reaction, the CO and steam react to produce carbon dioxide (CO<sub>2</sub>) and hydrogen gas (H<sub>2</sub>).

### Pressure Swing Adsorption

PSA separates the hydrogen from a mixture of H<sub>2</sub>, CO, CO<sub>2</sub> and methane. Adsorbent beds are used in cyclic operation, with control valves used to operate the beds during processing. Waste gases (CO, CO<sub>2</sub> and methane) are recycled back to the reformer furnace.

### Acid Gas Removal Unit (AGRU) - CCUS

Flue gas from the reformer and CO<sub>2</sub> coming from PSA are passed through a rich amine solvent to absorb the CO<sub>2</sub>, using steam for repurposing in enhanced oil recovery (EOR) or for compression and storage. Lean amine is recirculated back to absorption.

## Isolation Valves



Flowserve isolation valves deliver optimal performance in PSA applications by offering superior reliability and meeting tight shut-off requirements in fuel/feed/reactor isolation, steam production and bed isolation processes.

<b>Argus</b>	FK76, FK79 and others
<b>Valbart</b>	TMBV
<b>Worcester</b>	Series 51/52, 819/829 and others
<b>Durco</b>	TX3

## Control Valves



Our Valtek products offer high-cycle tight shut off for PSA operation, low noise, high-temperature steam valves, high-pressure drop BFW control and high-capacity outgassing amine level letdown.

<b>Valtek Linear</b>	MK1, MK100, MK100SC, MK200
<b>Valtek Rotary</b>	MaxFlo 4, Valdisk
<b>Valtek Severe Service Trim</b>	MegaStream, Diamondback, Stealth, CavControl

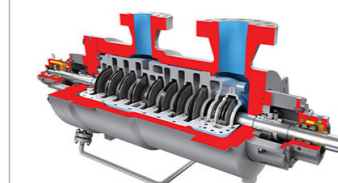
## Automation



Flowserve's Logix positioners coupled with Limitorque, Automax or Norbro actuators are designed for maximum reliability and deliver best in class performance.

<b>Automax</b>	Supernova
<b>Logix</b>	3800
<b>Limitorque</b>	Linear, Rotary, Scotch Yoke
<b>Norbro</b>	40/40R
<b>Worcester</b>	F39

## Pumps



Leak- and maintenance-free designs are critical for circulation and cooling pumps in blue hydrogen production. Low total cost of ownership helps manage costs, and energy recovery products improve process efficiency.

<b>Byron Jackson</b>	HDO
<b>Flowserve</b>	DMX, DVSR, HDX, HPRT, VTP, WIK/WIKO
<b>Worthington</b>	LNN
<b>IDP</b>	WCC, WXH

# GAS COMPRESSION, TRANSPORTATION AND STORAGE

To advance the hydrogen economy, the development of gas compression, transportation and storage infrastructure is critically important.

## Key process areas and product considerations

### Compression and Liquefaction

Hydrogen gas is typically produced at relatively low pressures and must be compressed and liquefied prior to transportation. Reciprocating, rotary, ionic or centrifugal compressors are used for gaseous hydrogen compression. The liquefaction process involves precooling the compressed hydrogen through a heat exchanger and then cooling fully through Joule-Thomson expansion to obtain liquid hydrogen. It is one of the most significant processes for storing hydrogen as a liquid and poses challenges related to extremely low temperatures.

### Transportation

Hydrogen is transported from the point of production to points of use via pipeline and in cryogenic liquid tanker trucks or gaseous tube trailers. Pipelines are typically deployed in regions with substantial demand whereas liquefaction plants, liquid tankers and tube trailers are deployed in regions with smaller-scale demand. Some transportation equipment such as tube trailers involve high pressures of up to 250 bar for gaseous hydrogen

### Storage

Hydrogen can be stored physically as either a gas or a liquid. Storage of hydrogen as a gas typically requires high-pressure tanks. Storing hydrogen as a liquid requires maintaining cryogenic temperatures and handling high pressures.

## Isolation Valves



Our isolation valves are designed to meet tough application requirements in gas compression, transportation and storage applications including large, tight shutoff for compressor isolation and cryogenic conditions. We can provide vacuum jackets for extreme cryogenic conditions to minimize thermal losses.

<b>Argus</b>	FK76, FK79 and others
<b>Worcester</b>	Various models, Cryogenic
<b>McCANNA</b>	Cryoseal
<b>Durco</b>	TX3, Cryogenic
<b>Valbart</b>	TMBV, Cryogenic
<b>Serck Audco</b>	Super H, Twin Isolation

## Automation



Our actuator and positioning products are both durable and sophisticated, an ideal balance that delivers reliable valve control in gas compression, transportation and storage applications.

<b>Logix</b>	3800
<b>Limitorque Electric</b>	MXb
<b>Limitorque</b>	LPS, LPC

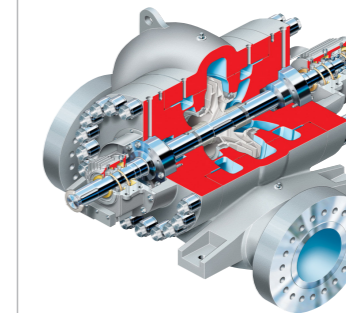
## Control Valves



Our Valtek and Valbart products offer fast stroke anti-surge for compression, deep cryogenic for liquefaction in preparation for storage and transport, and high-pressure drop control valves for storage transfer. We can provide vacuum jackets for extreme cryogenic conditions to minimize thermal losses.

<b>Kammer</b>	Coldflow, HpFlow
<b>Valtek Linear</b>	MK1, MK100, MK100SC, MK6
<b>Valtek Rotary</b>	Shearstream
<b>Valbart</b>	TMCBV

## Pumps and Seals



This step of the process requires leak- and maintenance-free products and refrigerant pumps for proper pre-cooling.

<b>Byron Jackson</b>	HDO
<b>Flowserve</b>	DVSR, WIK/WIKO, Gaspac Mechanical Seals
<b>IDP</b>	WCC





## Our commitment to energy transition

At Flowserve, our approach to energy transition begins and ends with our purpose: to make the world better for everyone. We understand that when we enable our customers to tackle climate change and address increasing energy demands through our innovative flow control solutions, we can make the world better – now and for generations to come.

Our approach is threefold. We are diversifying, decarbonizing and digitizing to support the global energy sector's transformation toward low-carbon sources.



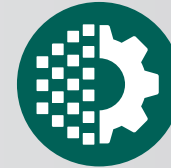
### DIVERSIFICATION

Our innovative portfolio of flow control solutions and services will support energy systems around the world to diversify the energy mix and adopt cleaner sources of energy.



### DECARBONIZATION

We will support the reduction of energy-related CO<sub>2</sub> emissions across the mix of energy sources through our innovative portfolio of flow control solutions and services.



### DIGITIZATION

We will enable improvements in efficiency, productivity, sustainability and safety of energy systems around the world through our digital solutions and services.

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