Swagelok® **Clean Energy Solutions**

Performance and reliability for the next frontier in energy technology

Swagelok

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Overview

Clean Energy Solutions for Today and Beyond

The need for sustainability is driving innovation throughout energy marketplaces. Clean energy technologies are helping to generate fuel and power more effectively than ever before.

High-integrity fluid system components—hydrogen electrolyzers, fuel cells, storage and containment, refueling infrastructure, and on-vehicle systems—are critically important. Swagelok offers the products and tailored services for demanding clean energy applications, including:

- **Safe storage and transfer at high pressures**, delivering the desired energy densities and operational ranges
- **Consistent delivery of critical components**, keeping production happening efficiently and on schedule
- **Long-term strength and corrosion resistance** by requiring stainless steels with higher alloy content and narrow specification

Swagelok has decades of experience and expertise in the containment and management of hazardous fluids and small-molecule gases under pressure. Our proprietary products, solutions, and services are conceived, designed, and delivered specifically to meet and exceed the needs of today's clean energy pioneers.

Solutions for Hydrogen

High-Integrity Solutions for an Evolving Market

The hydrogen energy market is moving quickly and evolving rapidly as the world seeks zero-emission energy options. Hydrogen producers, energy companies, infrastructure developers, and vehicle original equipment manufacturers (OEMs) are scaling production while tackling the unique challenges inherent to hydrogen containment and transfer.

Small-molecule hydrogen gas can escape from even the smallest connection gaps, leading to gas leaks and safety concerns

High-containment pressures (up to 1050 bar [15 200 psi]) require high-performance components where traditional options simply are not suitable

Hydrogen embrittlement and degradation can impact critical system components, compromising the materials' integrity and potentially leading to failures

We can help overcome these challenges and much more. We not only provide critical fluid system components, such as fittings designed specifically for hydrogen containment, but also materials science expertise and hands-on engineering services.

Solutions for Hydrogen Production

Generating Truly Green Energy

Achieving hydrogen's potential as a truly green energy source starts at the beginning. The electrolysis process, regardless of the electrolyzer design, requires high-integrity fluid system components that reliably transfer hydrogen and oxygen to their next destinations in the production process.

Leak-tight performance across a broad range of process equipment is required to maintain safety and profitability

High-quality materials can ensure that all critical components maintain their integrity, resisting the inherent challenges of hydrogen containment

Readily available parts and prefabricated systems for **quick scalability** can help hydrogen producers stay nimble and meet the growing demands for hydrogen power

We offer a broad range of suitable solutions for hydrogen electrolysis and fuel cell applications, made from the highest-quality materials that deliver performance and reliability. We can help you maintain efficient production with specialized knowledge and local service and support.

Solutions include:

- Tube fittings to 2"
- Manifolds
- Monel end connections (alkaline)
- Weld fittings
- Ball valves
- Needle valves
- Instrument manifolds
- Relief valves
- Measurement devices
- Regulators
- Filters
- Tubing
- Supports
- CNC tube bending
- Welding systems

Solutions for Hydrogen Distribution and Infrastructure

Building Robust and Reliable Systems

Getting cleanly produced hydrogen to end-use applications involves a closely linked chain of processing, storage, distribution, and transmission systems. High levels of fluid system performance are a necessity.

Achieving desirable energy density **necessitates high-pressure storage and containment**, requiring components rated for pressures up to 1050 bar (15 200 psi)

Leak-tight transfer is a necessity to maintain profitability and reliability as hydrogen moves throughout the distribution pipeline

Ease of installation and local service are key to quickly ramping up infrastructure

We offer the solutions you need to reliably distribute hydrogen, including a complete suite of high-performance products along with custom or standard preassembled systems, all backed by our specialized knowledge to help you accelerate the development of important infrastructure.

Solutions include:

- FK series fittings
- FK series valves
- Tube fittings
- Manifolds
- IPT MP/HP fittings
- Ball valves
- Needle valves
- Relief valves
- Measurement devices
- Tubing
- Supports
- CNC tube bending

Solutions for Hydrogen Compression and Refueling

Designing Refueling Stations for Safety

Safe and reliable refueling infrastructure is a necessity as hydrogen mobility scales up to handle an increase in demand. Applications like compressors, storage cylinders, priority panels, pressure control devices, and dispensers that deliver hydrogen need the highest-quality componentry.

Refueling stations require **safe operability**, enabling any driver to operate a dispenser with minimal risk

Components and connections must be able to **withstand rapidly changing temperatures** during dispensing cycles without experiencing degradation

Rapidly scaling infrastructure requires the ability to **quickly design and assemble complex systems** safely and reliably

Swagelok offers a complete portfolio of products for the compression, storage, and refueling of hydrogen.

Solutions include:

- Tube fittings
- FK series fittings
- Cone and thread fittings
- Tubing
- Regulators
- Hoses
- Valves
- Measurement devices

Solutions for Hydrogen Mobility

Durable Performance for Heavy-Duty Vehicles

Hydrogen fuel cell technology has major promise in heavy-duty vehicle applications. Reliable performance requires systems that can withstand the unique demands of on-road use.

Uncompromising vibration resistance is essential for critical connections in hydrogen fuel systems

Ease of installation keeps vehicles moving down the production line efficiently—a challenge that some OEMs struggle to overcome

OEMs pursuing just-in-time production strategies need parts and assemblies **delivered at the right time**

Emerging markets for additional vehicles and equipment have diverse needs and must **scale up quickly**

On-vehicle solutions from Swagelok—ranging from individual components to complete custom assemblies—deliver on these needs and more. They have demonstrated the specific performance characteristics to meet the required EC-79 and HGV 3.1 certifications for use in hydrogen vehicles and are accepted in the International Material Data System (IMDS).

Solutions include:

- Assembly-by-torque (AbT) fittings
- Tube fittings
- FK series fittings
- AFS ball valves
- CH series check valves
- FW and TF filters
- XS series excess flow valves
- Regulators
- All-metal hose
- Tubing
- CNC tube bending
- Preswaging

Solutions for Natural Gas

Dependable, Safe Performance for Natural Gas

Liquified natural gas (LNG) and compressed natural gas (CNG) are two of the most widely accessible means of reducing emissions associated with traditional gasoline- and diesel-powered energy production. Both continue to experience rapid worldwide growth.

Fluid systems for LNG and CNG require high-quality compression, transfer, and refueling systems at every level, from the source to the vehicle.

- LNG and CNG are stored at **pressures that can exceed 275 bar (4000 psi),** so any leak can result in significant hazards for operators
- OEMs looking to **maintain production schedules** need a supplier that can provide local inventory and understand their production requirements
- Elastomeric components in LNG and CNG systems play an important role by enabling reliable operation, and **materials compatibility** must be considered in materials selection

It is our mission to deliver solutions for any LNG and CNG application. Our long-standing experience in transportation markets, backed by our comprehensive service and support, can help overcome your toughest fluid system-related operational challenges.

Solutions for Natural Gas Distribution

Maintaining Reliable Pipelines

Dependable distribution of compressed and liquid natural gas from the production facility to the point of use is essential to operational success. Across the distribution system—where gas is compressed at high densities into tanks and transported to where it is needed—all components must be designed for maximum reliability.

Leak-tight performance is essential for reliable natural gas containment to eliminate fugitive emissions and protect the environment from escaping gas

Because natural gas is compressed to achieve maximum energy density, **high-pressure performance** is critical for any fluid system in the distribution process

Prefabricated system solutions can help infrastructure develop more quickly, with pretested and proven designs that deliver reliable performance

We back our high-integrity components with deep experience in high-stakes fluid handling. That means we are exceptionally qualified to help you develop critical new natural gas distribution infrastructure.

Solutions include:

- Tube fittings
- Ball valves
- Needle valves
- Check valves
- Measurement devices
- Tubing
- Supports
- CNC tube bending

Solutions for Natural Gas Compression and Refueling

Refueling Systems for Safety and Reliability

The continued proliferation of heavy-duty LNG and CNG vehicles requires widespread, reliable refueling infrastructure to meet the industry's need for increased capacity. LNG and CNG stations must contend with several challenges while achieving the highest levels of safety and reliability to protect end users and their vehicles.

Transferring LNG and CNG from storage to on-vehicle tanks requires **safe dispenser technology** that can accommodate significant changes in pressure and temperature

Maximized capacity for refueling stations is critical, with the ability to store large quantities of highly pressurized gases on-site for consumer distribution

Quickly scaling infrastructure requires **reliable and consistent** assembly of complex fluid systems

We can help meet these challenges with a range of solutions and services to meet your refueling infrastructure needs. We can deliver everything from individual components to preassembled systems to help infrastructure developers meet the pace of demand.

Solutions include:

- Tube fittings
- Natural gas hoses
- All-metal flexible hoses for LNG applications
- Ball valves
- Dispenser ball valves
- Manifolds
- Instrument manifold valves
- Tube supports
- Relief valves
- Regulators
- Measurement devices
- Bleed valves
- Tubing

Solutions for Natural Gas Mobility

Dependable Performance for Heavy-Duty Vehicles

According to NGV Global Group, nearly 30 million natural gas vehicles are operating worldwide. To support this industry's growth and volume, LNG and CNG fuel systems must provide uncompromising reliability and safety for the people who depend on these vehicles each day. That requires overcoming some unique operational challenges.

Fittings and connections in LNG and CNG applications must be able to reliably **withstand the vibrations** associated with a moving vehicle

As natural gas expands from high-pressure storage to lower pressure when fed to the engine, **gas temperature drops significantly**, so all parts of the system must be able to withstand these temperature changes

On-vehicle solutions from Swagelok deliver on these needs and more. They are certified to the ECE R110 and NGV 3.1 standards and are included in the IMDS.

Solutions include:

- Assembly-by-torque (AbT) fittings
- Tube fittings
- CNC tube bending
- Preswaged fittings for complete fuel lines
- Ball valves
- Check valves
- Hoses
- Measurement devices
- Pressure gauges
- Tubing
- Purge valves
- Bleed valves

Engineered for Clean Energy

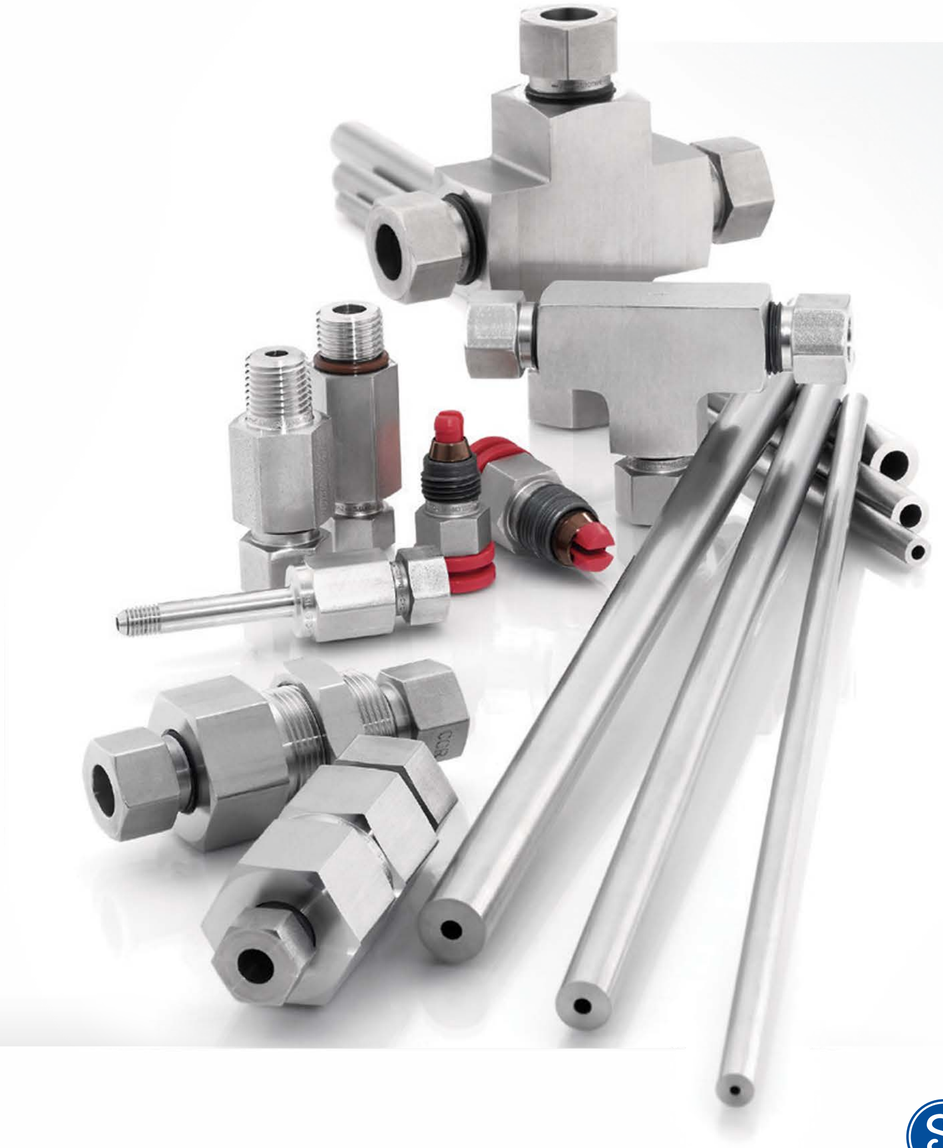
Designed for Greener, Higher Performance

Swagelok's clean energy components are designed to deliver the highest levels of safety, reliability, and high performance for a wide range of applications.

Swagelok® FK series fittings were developed specifically for use in hydrogen applications to deliver outstanding tube grip and leak resistance, as well as the ability to pull up by torque or turns. Their unique two-piece design and preassembled cartridge ensure correct ferrule orientation, visual confirmation of ferrule presence, and **simplified installation**.

Our **assembly-by-torque (AbT) fitting** technology further enables technicians to install fittings by torque, helping **reduce production time** and complexity on assembly lines. AbT fittings deliver enhanced efficiency and reliable performance across a range of applications.

Our **stainless steel components incorporate elevated nickel and chromium** levels that promote **enhanced corrosion resistance** and greater ductility when interacting with hydrogen, natural gas, methane, or ammonia.



Design and Assembly

Production Made Easier

Strained workforces, a lack of skilled technicians, and supply chain complexities can make efficient production more difficult. Swagelok can provide the support you need with custom, ready-to-install subsystems and assemblies built to your exact specifications.

Swagelok® Custom Solutions can consist of either a few components or complete fluid systems, including gas fill panels, or fluid system assemblies to integrate into dispensers, compressors, and fuel line solutions. We work with you to understand the application and develop a configuration that meets your needs.

All assemblies are built with Swagelok's high-quality fluid system components. We can also incorporate third-party products, including wiring, automation, transmitters, relays, motors, and more. We produce a professional, repeatable design complete with testing, inspection, and packaging. All solutions are backed by our Swagelok Limited Lifetime Warranty.

CNC tube-bending services provide high volumes and complex tube bends for your fuel delivery systems, saving you the work of manual bending

Preswaged tubing and fittings take a critical assembly process off your hands, saving labor and production time

Engineering Services

Support for Your Needs

Swagelok provides a complete suite of services for the alternative fuels industry, helping OEM and infrastructure developers build solutions more quickly, easily, and reliably.

Our experienced **field engineering team** can be accessed around the world and can help you identify and solve application challenges, troubleshoot problems, and recommend materials based on factors that contribute to corrosion, hydrogen embrittlement, and chemical compatibility issues

We provide **global reach and local support**—no matter where in the world you operate, there is an authorized Swagelok sales and service center ready to meet your needs

Materials Science

The Right Materials for the Right Applications

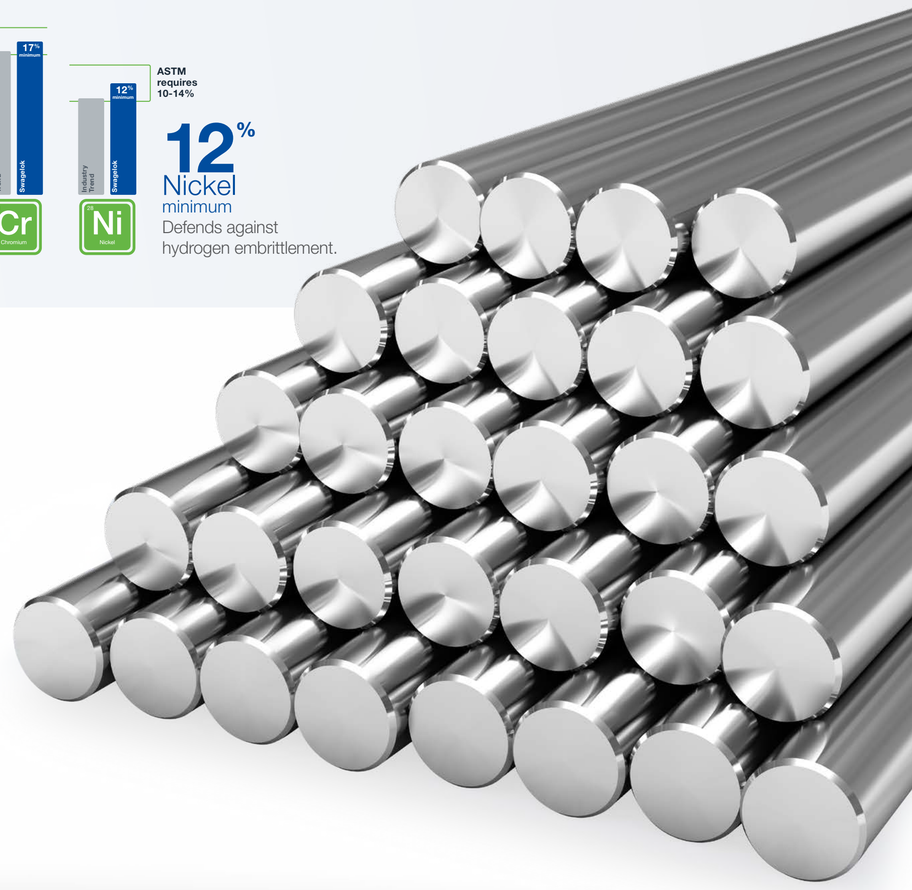
Today's clean energy applications come with some unique operational demands—and the wrong alloy can lead to potential failures.

Hydrogen molecules are among the smallest in the natural world, and containing them requires the **highest grades of stainless steel**. Swagelok 316 stainless steel is specifically formulated with elevated levels of nickel and chromium for enhanced strength and resistance to hydrogen embrittlement, as well as weather-related corrosion resistance.

Elastomeric components play an important role in reliable operation, and chemical compatibility must be considered in materials selection. For example, ethylene propylene performs well in cold temperatures but is not chemically compatible with hydrocarbons that are present in LNG and CNG.

Trust Swagelok to help you specify the right materials for on-vehicle fuel systems, tube trailers, infrastructure panels, dispensing systems, and more. Swagelok products are made of alloys with at least two, but often up to ten, different elements in optimized concentrations, granting superior corrosion resistance that helps our products perform better.

[Learn more about Swagelok materials selection]



Training

Develop the Essential Skills Your Team Needs

Capitalizing on the opportunity presented in emerging transportation markets requires **skilled teams** that can reliably work, assemble, and operate critical gas systems.

A well-trained team can help ensure your approach is consistent and your standards are upheld on every installation. Swagelok offers a variety of training opportunities on tube fitting installation and inspection, tube bending, hose routing, orbital welding, cone and thread installation for medium- and high-pressure applications, and much more.

Our experienced educators help fluid systems professionals around the globe get up to speed on fluid system best practices, covering many areas from trends and technology to installation and safety.

Learn more—discover Swagelok training

Contact Us

We provide localized service to our customers around the world through our strategically located global network of authorized Swagelok sales and service centers.

Discover how you can build and operate safe, reliable alternative fuel systems with Swagelok. Locate your local sales and service center today.