

Swagelok[®] Transportation Solutions

Performance and reliability for the next frontier in fuel technology



Swagelok[®]



Overview

Uncompromising Performance: Green Mobility Solutions for Today and Beyond

The need for sustainability is driving innovation across the transportation market. Alternative fuel technologies are helping buses, trucks, and other vehicles operate more cleanly and efficiently than ever before.

Safety, reliability, and range are top priorities. On-vehicle systems and refueling infrastructure require high-integrity system components to contain high-pressure and small-molecule gases. **Swagelok can help**, with high-performance products and solutions specifically engineered for the toughest challenges in the alternative and specialty fuels markets.



Safe operation requires leak-tight containment systems, capable of storing alternate fuels at high pressures for desired operational range.



Consistent delivery of critical, custom parts and assemblies is essential to keep vehicle production happening quickly and on schedule.



Our stainless steel alloy content is higher and more narrowly specified than ASTM standards for strength and corrosion resistance.

Trust Swagelok to deliver a wide range of critical components for use in many types of alternative fuel applications, including the infrastructure that produces, transports, compresses, and stores gases for on-vehicle use. Swagelok is dedicated to working with you to deliver the solutions you need to build a cleaner environment.

Explore all the ways we can help.



Solutions for Hydrogen High-Integrity Solutions for an Evolving Market

The hydrogen market is moving quickly and evolving rapidly. Vehicle original equipment manufacturers (OEM) and infrastructure developers are scaling production while tackling the unique challenges inherent to hydrogen containment and transfer.

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

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.

Swagelok can help overcome these challenges and much more. With critical fluid system components and fittings designed specifically for hydrogen containment, backed by unmatched materials science experience and a suite of supplemental services, we are a supplier that you can trust.

Explore our solutions for [hydrogen on-vehicle](#) and [infrastructure applications](#).



Solutions for On-Vehicle Hydrogen Performance for Light- to Heavy-Duty Trucks and Buses

Hydrogen fuel cell technology has demonstrated major promise for light- and heavy-duty vehicle applications. Reliable performance requires systems built with components that can withstand the unique demands of on-road use. [Swagelok solutions for hydrogen vehicles](#) have been developed to meet each of these needs.

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

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

Ease of installation is critical to keep vehicles moving down the production line efficiently—a challenge that some OEMs struggle to overcome.

Emerging markets for additional vehicles and equipment have diverse needs for alternative fuel components. Proven performance can help OEMs **scale 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 required EC-79 and HGV 3.1 certification for use in hydrogen vehicles and are accepted in the International Material Data System (IMDS).



Solutions include:

- Assembly-by-torque (AbT) fittings
- Swagelok® tube fittings
- FK series medium-pressure fittings
- AFS ball valves
- CH series check valves
- FW and TF filters
- XS series excess flow valves
- All-metal hose
- Swagelok® tubing
- CNC tube bending
- Preswaging

Solutions for Hydrogen Infrastructure High-Integrity Systems for Infrastructure

Reliable refueling infrastructure is a necessity as hydrogen transportation scales up to handle an increase in demand. Applications like hydrogen tube trailers, electrolyzers, 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.

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

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

Trust Swagelok to deliver a high-quality suite of hydrogen infrastructure solutions, including:

- Swagelok® tube fittings
- Cone and thread fittings
- Hoses
- FK series medium-pressure fittings
- Standard- and medium-pressure, and cone and thread tubing
- Valves
- Measurement devices



Solutions for Natural Gas Outstanding Performance in Compressed Natural Gas

Liquefied natural gas (LNG) and compressed natural gas (CNG) have become two of the most attainable means of dramatically reducing the emissions associated with traditional gasoline- and diesel-powered vehicles and equipment. Both are seeing rapid worldwide adoption.

Capitalizing on the potential of LNG and CNG requires high-quality containment and transfer systems at every level, from the source to the vehicle.

LNG and CNG are stored at **pressures that can exceed 275 bar (4000 psi)**. Any leak can result in significant hazards for operators.

OEMs looking to **maintain production schedules** need a supplier that can provide local inventory of components and that will take the time to understand their production needs.

Elastomeric components in LNG and CNG systems play an important role enabling reliable operation, and **chemical compatibility** must be considered in materials selection.

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

Explore our solutions for [on-vehicle applications](#) and for [LNG and CNG refueling infrastructure](#).



Solutions for On-Vehicle Natural Gas Reliability for Light- to Heavy-Duty

By the end of 2021, it's expected that 30 million natural gas vehicles will be operating worldwide. As the technology continues to mature, LNG and CNG fuel systems must provide uncompromising reliability and safety for the people who depend on these vehicles each day. That requires overcoming several important operational challenges.

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

As LNG and CNG expand from high-pressure storage to lower pressure when fed to the engine, **gas temperature drops significantly**. 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 International Material Data System (IMDS). Solutions include:

- Assembly-by-torque (AbT) fittings
- Swagelok® tube fittings
- CNC tube bending
- Preswaged fittings for complete fuel lines
- Ball valves
- Check valves
- Hose
- Pressure gauges
- Swagelok® tubing
- Purge valves
- Bleed valves



Solutions for Natural Gas Infrastructure Achieving Safe and Reliable Refueling

The proliferation of LNG and CNG vehicles requires widespread, reliable refueling infrastructure to realize the technology’s true potential. LNG and CNG stations must contend with several challenges while achieving the highest levels of safety and reliability to protect drivers refueling vehicles.

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

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

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

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

LNG and CNG infrastructure solutions include:

- Swagelok® 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
- Swagelok® tubing

Many Swagelok products meet the NGV4.X for dispensing systems. In addition, we can work directly with you to achieve compliance with regional standards and specifications.



Swagelok Components Designed for High-Performance Fuel Systems

Swagelok's alternative fuel components are designed to deliver the highest levels of safety, reliability, and high performance for on-vehicle and infrastructure 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 **drive down production time** and complexity on assembly lines. AbT fittings deliver enhanced efficiency and reliable performance across a range of on-vehicle and infrastructure applications.

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

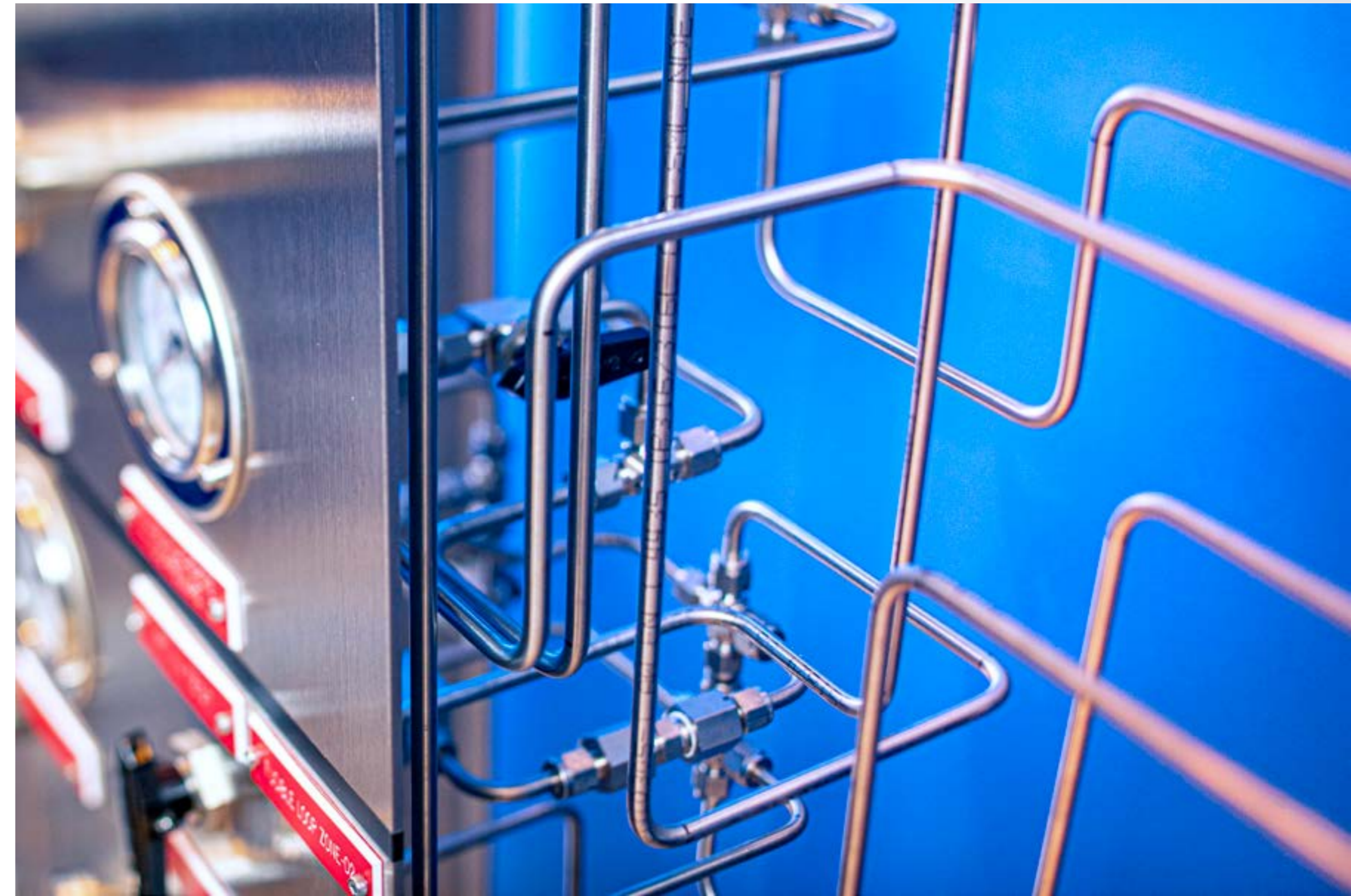


Design and Assembly Production Made Easier

Strained workforces, a lack of skilled technicians, and supply chain complexities are just some of the challenges that can make efficient production more difficult than necessary. Swagelok can provide the support you need with custom subsystems and assemblies built to your exact specifications, ready to be installed.

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. Our approach is collaborative: We work closely with you to ensure we understand the application and are developing the configuration that most completely 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 Services Support for Your Needs

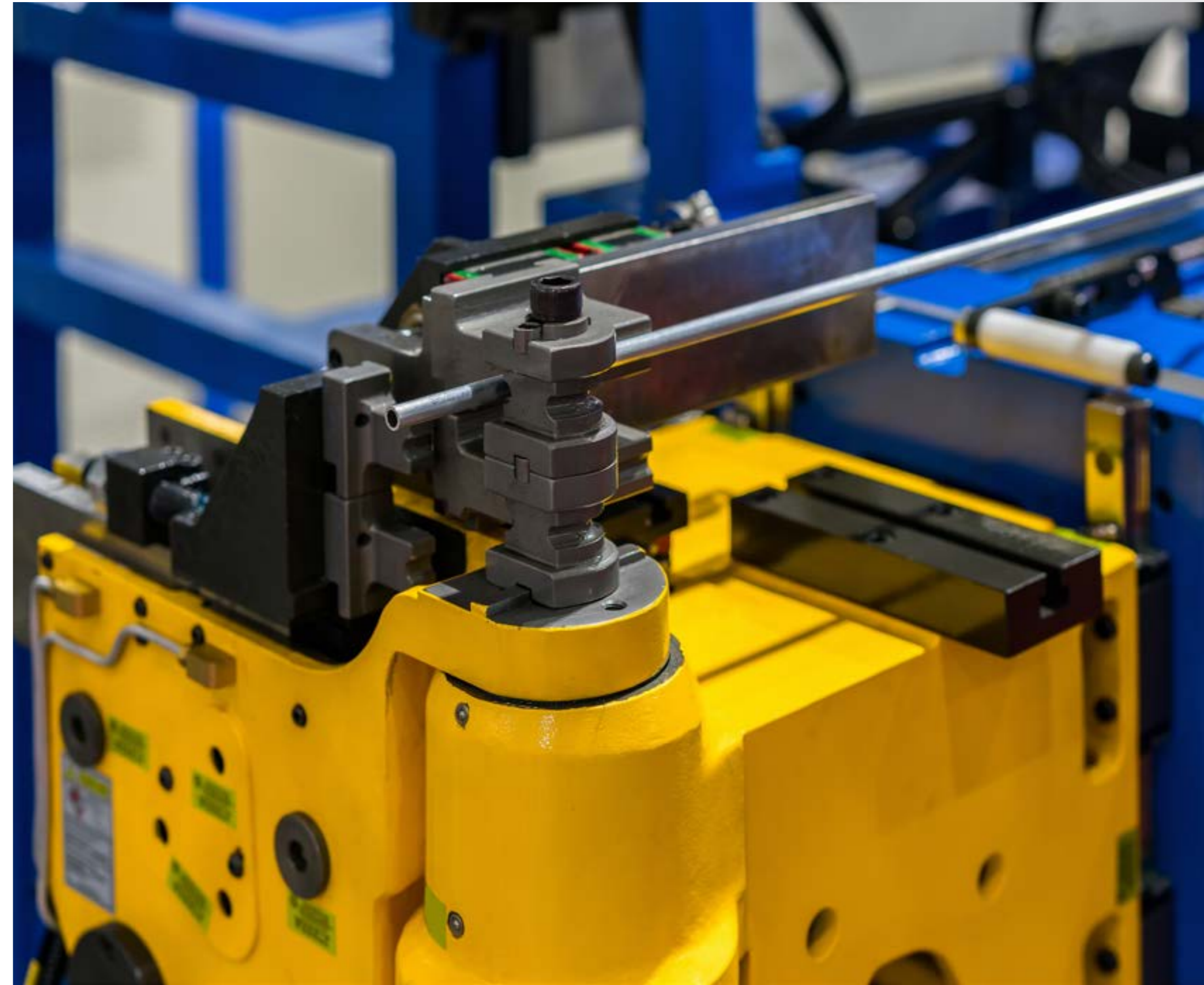
Swagelok provides a complete suite of services for the alternative fuels industry, helping OEM and infrastructure developers build solutions more quickly, easily, and reliably.

CNC tube-bending services can deliver 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.

Our experienced **field engineering team** can help you identify application challenges, troubleshoot problems, and provide actionable solutions.

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.



Swagelok Materials Science The Right Materials for the Right Applications

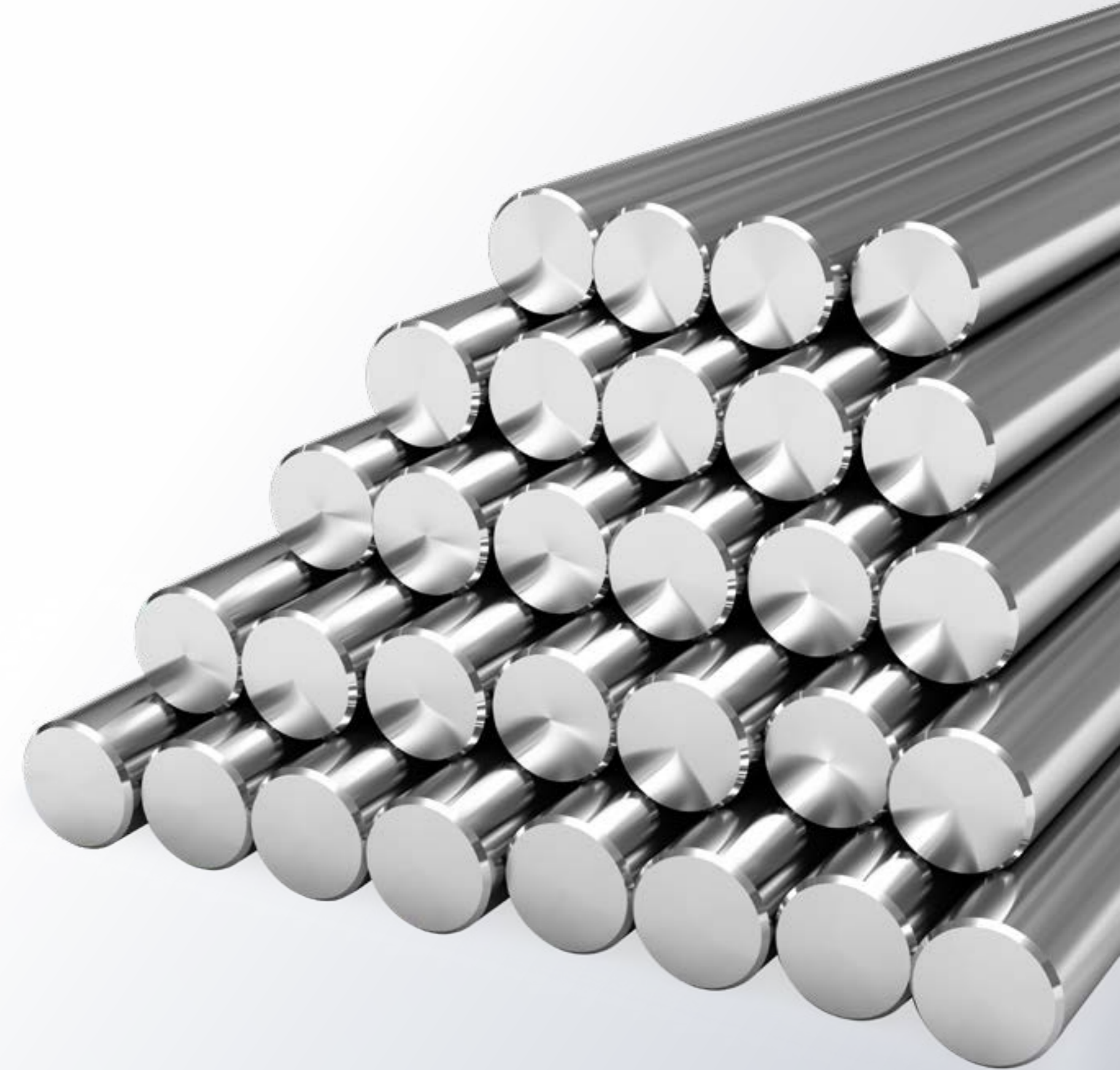
Today's green mobility and transportation applications come with some unique operational demands—and the wrong alloy can lead to potential failures.

Only the highest grades of stainless steel can stand up to the challenge presented by hydrogen molecules, which are among the smallest in the natural world. Swagelok 316 stainless steel is specifically formulated to overcome this phenomenon (called embrittlement) with enhanced strength and corrosion resistance.

On-road corrosion can be a major failure mode for common alloy system components. A salt-treated road in the wintertime, for example, can cause challenges with system components that lack adequate corrosion resistance. Lesser-quality stainless steel formulations with low nickel and chromium content are more susceptible to these kinds of corrosion issues.

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**. We simplify selection with our deep understanding of factors that contribute to corrosion and hydrogen embrittlement. 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.



Swagelok 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 that your approach is consistent and that 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 have helped 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.



Discover the Possibilities With Swagelok

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.



Index

Overview

**Uncompromising Performance:
Green Mobility Solutions for Today and Beyond** ____ 2

**Solutions for Hydrogen
High-Integrity Solutions for an Evolving Market** ____ 3

**Solutions for On-Vehicle Hydrogen
Performance for Light- to Heavy-Duty
Trucks and Buses** _____ 4

**Solutions for Hydrogen Infrastructure
High-Integrity Systems for Infrastructure** _____ 5

**Solutions for Natural Gas
Outstanding Performance in Compressed
Natural Gas** _____ 6

**Solutions for On-Vehicle Natural Gas
Reliability for Light- to Heavy-Duty** _____ 7

**Solutions for Natural Gas Infrastructure
Achieving Safe and Reliable Refueling** _____ 8

**Swagelok Components
Designed for High-Performance Fuel Systems** ____ 9

**Design and Assembly
Production Made Easier** _____ 10

**Swagelok Services
Support for Your Needs** _____ 11

**Swagelok Materials Science
The Right Materials for the Right Applications** ____ 12

**Swagelok Training
Develop the Essential Skills Your Team Needs** ____ 13

Discover the Possibilities With Swagelok _____ 14

