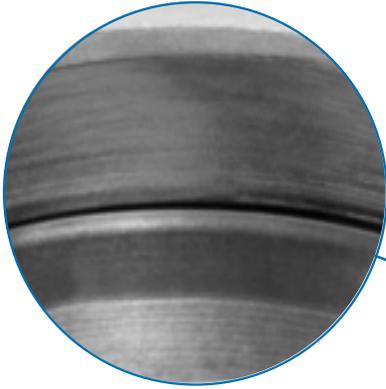


316 Stainless Steel Swagelok® Tube Fittings with Advanced Geometry Back Ferrules



Simplify
Installation,
Improve
Performance, and
Reduce Total
Installed Cost

Introduction

Since the original two-ferrule Swagelok tube fitting was introduced in 1947, fluid systems designs have continued to shift from high-volume/low-pressure to low-volume/high-pressure to meet financial, environmental, and performance requirements. These new low-volume/high-pressure systems call for increased internal and external pressures, vacuum levels, flow velocities and shifts, vibration levels, and shock and impulses. As a result, mechanical demands on tube fittings, tubing runs, and other system-related equipment have increased as well.

The Swagelok two-ferrule tube fitting has earned a global reputation for consistency, quality, and performance, supported by our continuous product improvement efforts. In order to provide consistent, leakfree connections to fluid system users, our experience shows that a tube fitting has to meet the following requirements:

- Offer reliable installation over a range of field conditions, since improper make-up and tightening remain the leading causes for leakage.
- Cope with the wide variation in tubing characteristics, including differences in wall thickness, hardness, ovality, and burst pressures.
- Deliver a predictable, consistent “feel” to installers, who sometimes judge installation quality by effort (torque) rather than the recommended one-and-one-quarter-turn installation practice. Fittings that require high installation torque or that vary widely in the “feel” and effort required to achieve complete pull-up may cause installers to improperly tighten components and severely degrade tube fitting performance.

How Two-Ferrule Tube Fittings Operate

Tube fittings depend on a balance of factors to ensure proper installation and performance. In a two-ferrule tube fitting design, the back ferrule moves the front ferrule forward to spring load the fitting assembly, burnish and seal with the fitting body, and create the primary tubing seal. The back ferrule also swages the tube to provide the grip needed to keep the fitting and tubing firmly in place.

To swage and grip the tube properly, the back ferrule’s leading edge must be sufficiently harder than the tube. Two methods of producing this differential hardness may be employed—complete surface hardening of the back ferrule or selective hardening of only the nose of the back ferrule.

The use of complete surface hardening on a conventional back ferrule can have several drawbacks. First, it typically increases installation torque because a surface-hardened, conventional back ferrule is unable to flex or “hinge” downward to improve swaging action on the tube. Instead, it must be wedged into position using installer torque, and as a result, more torque typically is required. Second, because it is not engineered to hinge and absorb installer torque on remakes, a conventional

In consideration of these factors, over the last 50 years, Swagelok has implemented continuous improvements to its tube fitting products that help customers make correct, leakfree installations, easily and consistently. These enhancements include precision geometry to improve the swaging of the back ferrule nose onto the tubing, the design of gaugeable fittings and gap inspection gauges, and training seminars to instruct installers worldwide in the requirements for making safe, leakfree connections.

Industry continues to demand that tubing installations and operations be more reliable, controllable, repeatable, predictable, and economical. Therefore, it was logical to take the Swagelok tube fitting to the next level of performance to add even more value. The fundamental challenge in developing the Swagelok tube fitting with advanced geometry back ferrules was to maintain or even further reduce installation time and effort, improve performance, and maintain compatibility with the original design of the Swagelok tube fitting—the world’s most widely installed instrumentation tube fitting.

surface-hardened back ferrule can tend to over-drive the front ferrule when remade. This condition can potentially damage the tubing and fitting body and compromise the front ferrule action required for consistent gas-tight remakes.

Compared to fittings that employ complete surface-hardened back ferrules, the original design of the Swagelok tube fitting established a different balance of factors in installation and performance. Through the use of a selectively hardened back ferrule, Swagelok reduced installation torque while providing the swaging and gripping action needed to perform in combination with a wide variation of commercial grade tubing. In manufacturing its back ferrules, Swagelok employed a proprietary metallurgical process that selectively hardened the nose of the back ferrule, yet left the center section and rear flange softer. During make-up, this softer center section acts as a hinge point when force is applied to the flange. This hinging mechanism helps limit the amount of torque required by the installer, yet delivers the right amount of swaging action through the nose of the back ferrule.

Evolution of the Advanced Geometry Back Ferrule

While the performance of the original design of the Swagelok tube fitting has been outstanding with regard to 316 stainless steel tubing, alloys of greater strength and hardness posed a significant challenge to the original design. A specific challenge from a customer led us to examine the requirements for a tube fitting built of super duplex stainless steel, a material substantially stronger and harder than 316 stainless.

To meet this challenge, we developed an advanced geometry back ferrule design that balances the performance requirements of hard, higher pressure tubing, with a consistent, easy-to-achieve target for proper installation. The improved Swagelok tube fitting design (Figure 1, next page) incorporates a patented new back-ferrule geometry with an improved engineered hinging action and a new, patent-pending process for full surface hardening and enhanced corrosion resistance.

The improved engineered hinging action of the back ferrule (Figure 2, next page) provides several benefits:

- It advances and seals the front ferrule predictably and accurately.
- It flexes to maintain installation torque at a predictable and manageable level, even on hard materials.
- It smoothly and efficiently delivers more swaging energy earlier in the pull-up process. As a result, it reduces the potential for improper installation and leakage in cases where the fitting is less than properly tightened.

- Its proprietary metallurgy and hinging action can absorb excess torque inputs to help prevent overdriving of the front ferrule, thus ensuring more predictable gas-tight sealing during remakes.

The success of this design in meeting the requirements for super duplex tubing convinced Swagelok of the value in utilizing the same basic design in its 316 stainless fittings as well.

Improved Ferrule Performance

As the nut is turned during pull-up, the back ferrule first drives the front ferrule between the tubing and the fitting body seat, creating a primary seal. As resistance to forward motion increases, the back ferrule hinges radially inward, transferring force downward to swage the surface of the tubing and produce a consistent, firm grip.

The shape and metallurgy of the advanced geometry back ferrule are designed so that the ferrule hinges inward to swage and grip the tubing before the front ferrule is driven past its optimum sealing position. In addition, the patented geometry of the ferrule avoids generating an exposed large stress riser on the tube, a deficit typical of bite-type fittings. In addition, the radial colletting action of the back ferrule grips the tube away from the swaging point to actually enhance vibration endurance. The result is an extremely robust, easy-to-install, and consistently reliable tube fitting technology capable of meeting the demands of modern industrial fluid-system applications.

Benefits Summary: Swagelok Tube Fittings with Advanced Geometry Back Ferrule

The Swagelok two-ferrule tube fitting offers predictable, leak-tight performance up to the burst pressure of AISI 316 and 304 stainless steel tubing. A summary of its benefits include:

- **Wider Target for Proper Installation:** The engineered hinging action of the advanced geometry back ferrule delivers energy to not only seal the front ferrule, but also to deliver greater swaging action throughout the pull-up process. As a result, this fitting reduces the potential for improper installation and system leakage, even in cases where the fitting was less than properly tightened.
- **Enhanced Gas Seal:** The back ferrule hinge delivers steady force to seal the front ferrule consistently on a wide range of tubing. Because the advanced geometry back ferrule can hinge and absorb more energy than a conventional hardened back ferrule, this design reduces the potential for overdriving the front ferrule, thereby ensuring reliable operation and gas seal for repeated remakes.
- **Vibration Fatigue Resistance:** The engineered back-ferrule hinging action delivers a more consistent radial colletting action to give improved support to the tube behind the point of grip. This colletting protects the swaged area of the tube more effectively from system vibration and fatigue.
- **Greater Margin of Performance on Commercial Tubing:** Textbook calculations, such as Lamé's formula for determining minimum rupture pressure of a tube, use the minimum allowable ultimate tensile strength, minimum allowable wall thickness, and maximum allowable outer diameter for tube burst calculations—as they should. However, these calculations offer a conservative estimate of the tube's pressure-containing

ability. In reality, stainless steel tubing manufacturers do not always run their processes for the minimum required material strength values cited by ASTM and other standards for determining the rupture pressure of a tube. The result is stronger, harder tubing with burst pressures often significantly higher than what occurs under least case conditions. The Swagelok tube fitting is robust enough to grip and exceed the burst pressure of these stronger, available tubing materials. In addition, the uniformly surface-hardened design of the advanced geometry back ferrule offers high corrosion resistance.

- **Compatibility with Original Design Swagelok Tube Fittings:** The patented Swagelok fitting pulls up using the same one-and-one-quarter-turn procedure as the original-design of the Swagelok tube fitting. In addition, the Swagelok fitting with advanced geometry back ferrule uses the same installation inspection gauges as before. However, what every installer will notice is a more consistent feel, from a more consistent range of torque on every pull-up to an even more consistent, leak-free connection.
- **Applicability to New Alloys:** The Swagelok tube fitting demonstrates it is practical to develop an easy-to-install, high-performance tube fitting that can be built using non-standard alloys, such as super duplex steel, despite their increased strength and advanced mechanical properties.

New Surface Hardening Methods Used in Advanced Geometry Back Ferrules

Swagelok has international patents and patents pending on a number of methods developed for producing uniform, very hard, and corrosion-resistant stainless steels. These methods employ carbon-solution, hardened surface treatments essentially lacking in metal carbide precipitates that can permit corrosion. Case carburization or case hardening is accomplished by elevating the temperature of stainless steel to allow free carbon diffusion into its surface, resulting in a uniform hard layer on the metal. This method avoids temperatures that create metal carbide precipitates.

Solution hardening of stainless steels was pioneered by Dr. B.H. Kolster in the Netherlands; he published the results of his work in 1983. Since that time, Swagelok and several other organizations have pursued processes for achieving this carburization effect on a range of products. Swagelok is the only manufacturer of tube fittings to have independently developed and have international patents and patents pending for commercial-scale processes to produce case carburization of ferrules for tube fittings. Swagelok's expertise in surface-hardening techniques for stainless steels was essential to the successful development of the patented geometry and hinging action of the advanced geometry back ferrules used in its 316 and super duplex tube fittings.

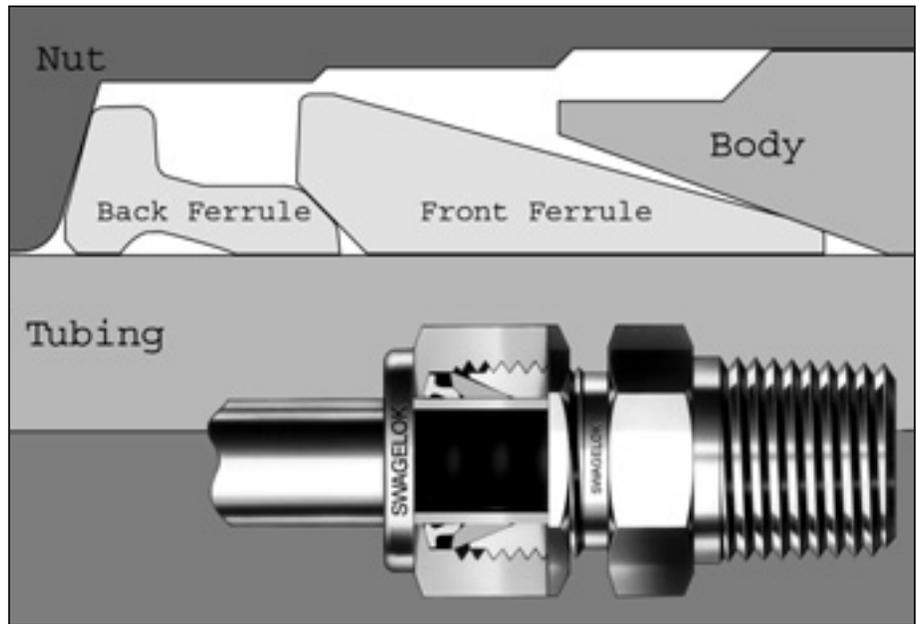


Figure 1:
316 SS Swagelok Tube Fitting with Advanced Geometry Back Ferrules Prior to Make-up

The elements of the fitting are depicted in cross-section prior to make-up: the fitting nut (top), the advanced-geometry back ferrule (left), the front ferrule (center), and the fitting body (right). The tube wall section is shown below the ferrules and body.

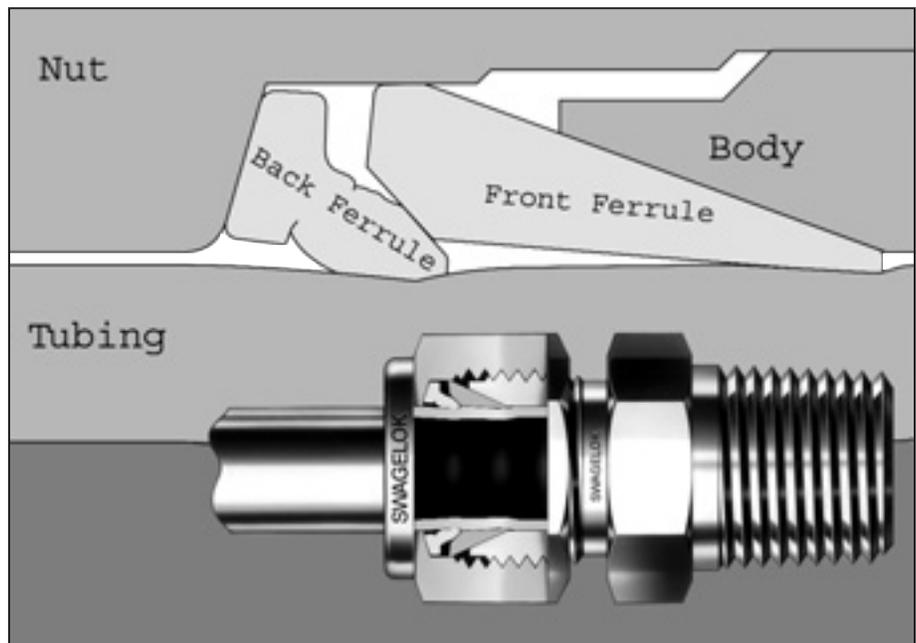


Figure 2:
316 SS Swagelok Tube Fitting with Advanced Geometry Back Ferrule After Make-up

During make-up, the front ferrule (center) is driven into the body of the fitting (right) and the tube (bottom) to create primary seals (tube and body), while the back ferrule (left) hinges inward to create a strong grip on the tube. The rear ferrule geometry allows for an improved engineering hinging action that translates axial (forward) motion into radial swaging action on the tube, yet operates with a low input force (torque) requirement. The improved radial colletting action of the back ferrule (the area to the left of the swage point) isolates and protects the swaged area of the tube, preventing the exposed vibration stress riser that is typical of bite-type fittings.