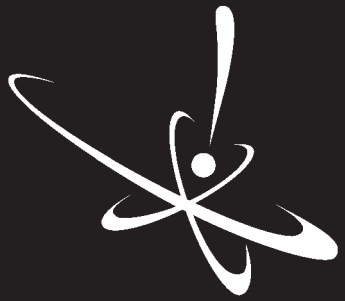

Restek
Performance
Coatings

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Restek Corporation Performance Coatings Division specializes in innovative surface treatments for stainless steel, steel, alloys, glass, and other materials. Our patented, exclusive processes reduce interactions between pathway surfaces and active compounds, inhibit coking, resist corrosion, and offer other important advantages.

Restek's experience with surface coatings began in 1987. A client contacted us to pacify the metal surfaces of their new explosives detector because we were known in the analytical industry as the silicone coating experts. It "could not be done" according to the literature—but we developed technology to coat intricate metal parts with an inert layer, preventing low ppt levels of explosives from adsorbing to the metal surface. Driven by this success, we applied our technology to capillary gas chromatography columns, essentially duplicating the inertness of glass within metal tubing. Our highly robust stainless steel columns were perfect for process analyses. The end product from this work was Silcosteel® treatment for stainless steel tubing. Silcosteel® treated tubing currently is used in analytical testing apparatus made by all major manufacturers of gas chromatography sampling and analysis equipment.

It "could not be done" according to the literature, but we did it.

Restek surface treatment processes do not rely on line-of-sight deposition. The chemical vapor deposition process ensures all surfaces are treated uniformly—even in corners, at holes, or at machined ridges.

Since our initial project, Restek's coatings experts have developed a family of surface treatments to address specific needs and thereby enhance the performance of system components in many applications, spanning multiple industries and market areas. Restek treated components increase the lifetime of stack monitoring equipment exposed to sulfuric acid. Silcosteel®-AC treated injector nozzles have longer service life because coking is inhibited. Sulfinert® treated sampling equipment increases the reliability of process measurements in refineries and petrochemical plants. A mass spectrometer manufacturer demands Silcosteel® treated parts to increase instrument sensitivity for analyzing pesticides. Restek air sampling equipment has been used in diverse environments, from city air to submarine cabins to NASA space shuttles.

Some 17 years ago we were a small group of young, eager chemists willing to try anything. Now, there are many Restek scientists eager to advance our surface treatment technology, and our visions have evolved into highly reproducible, patented surface treatments applied with computer-controlled precision. The Performance Coatings Division has evolved into a separate division of Restek, devoting its energies exclusively to meeting your surface passivation needs. This brochure highlights applications that exhibit marked improvement because of Restek technologies. Discover our capabilities here, then challenge us. Give us your toughest surface activity problems, and watch our team innovate. Restek has been turning visions into reality since the earliest days of our company. Let us do what "cannot be done" for you.

Restek's surface treatments are:

Silcosteel®	A general-purpose passivation layer for steel and stainless steel. U.S. patent 6,511,760.
Silcosteel®-AC	Dramatically reduces carbon buildup on stainless steel components. U.S. patent 6,444,326.
Silcosteel®-CR	A corrosion resistant layer that increases the lifetime of system components in acidic environments containing hydrochloric acid, nitric acid, sulfuric acid, or seawater. Patent pending.
Silcosteel®-UHV	Greatly reduces outgassing from components of ultra-high vacuum systems. Patent pending.
Siltek™	The ultimate passivation for treated components, from glass to high nickel alloys of steel. U.S. patent 6,444,326.
Sulfinert®	A required treatment for metal components when analyzing for parts-per-billion levels of organo-sulfur compounds. U.S. patent 6,444,326.

Restek Surface Treatments

Restek passivation and surface protection layers are deposited using a chemical vapor deposition (CVD) process in which the item to be treated is heated under vacuum in a large oven. Our current capacity enables us to treat items up to 6 feet long, or continuous lengths of coiled tubing exceeding 2000 feet (600 meters). Items that can be evacuated, such as gas chambers, can have a volume of up to 3.5 cubic feet.

When the item has been heated to the appropriate temperature, the reacting gases that form the protective surface are introduced, depositing a durable, amorphous layer that grows and overlays itself multiple times. The reaction layer penetrates into the lattice of the treated piece and binds solidly. Consequently, it is possible to work a piece, such as bending a length of treated tubing, without creating cracks, flakes, or other flaws in the layer. By controlling the variables in the process, we control the layer type and thickness. Layer thickness ranges from 0.03μm to 30μm, controlled to our specifications.

Surface Passivation

The surface of a system component might be made inert to reduce adsorption or to eliminate the potential for catalyzing reactions. Traditionally, glass linings have been employed to reduce surface activity. Problems with preparing a glass-lined system include the need for careful handling and the difficulty of coating corners, weld seams, and bends, with consequent occurrence of coating flaws. Operating a system with glass-lined components introduces other difficulties, not the least of which is fragility.

Restek offers two treatments, Siltek™ and Silcosteel®, that are ideal alternatives to glass linings for passivating many types of surfaces. A Siltek™ or Silcosteel® layer provides complete surface isolation while maintaining all the ruggedness of the untreated component. These layers are applied over the entirety of the surface, using a chemical vapor deposition process that does not depend on line-of-sight; corners, bends, and seams are uniformly coated.

As strong as steel, as inert as glass.

In most situations Siltek™ treatment is the ideal choice for ultimate inertness. The Siltek™ layer is applied at a thickness of up to 0.12μm. At this thickness even parts-per-billion levels of reactive materials will be stable during storage or transfer. A Silcosteel® layer provides equivalent protection for parts-per-million levels of reactive materials.

A selection of Silcosteel®- and Siltek™-treated tubing and fittings are available from stock. All coatings are applied to customer supplied items on a custom basis—see Custom Coating Services on page 32.

Compatibility with Restek Performance Coatings

	Excellent	Good	Poor
Aldehydes	•		
Acetic Acid	•		
Acetone	•		
Alcohol	•		
Amines			•
Ammonium Hydroxide			•
Arsenic	•		
Aromatics	•		
Atmospheric/Humidity Corrosion	•		
Benzene	•		
Brine		•	
Carbon Dioxide	•		
Carbon Disulfide	•		
Carbon Monoxide	•		
Dimethyl Disulfide	•		
Dimethyl Sulfide	•		
Ethyl Mercaptan	•		
Fatty Acids	•		
Ferric Chloride		•	
Formaldehylde	•		
Hydrocarbons	•		
Hydrochloric Acid		•	
Hydrofluoric Acid			•
Hydrogen Peroxide	•		
Hydrogen Sulfide	•		
Ketones			
Marine Environments	•		
Mercury	•		
Mercury Oxides	•		
Methyl Mercaptan	•		
Nitric Acid		•	
Phosphoric Acid		•	
Potassium Hydroxide			•
Salt Spray		•	
Sodium Hydroxide			•
Toluene	•		

Inertness to Sulfur Compounds

Because they contribute to air pollution and are known catalyst poisons, sulfur compounds are increasingly being targeted for monitoring to extremely low levels in air and in ethylene/propylene. Strict limits for sulfur content in gasoline and diesel fuel are to be achieved by 2007.

Many key organo-sulfur compounds are adsorbed to or react with steel or stainless steel surfaces. To address this issue Restek developed the Sulfinert® surface treatment process. Sulfinert® treatment eliminates interaction between organo-sulfur compounds and steel. The figures on the next two pages demonstrate the benefit of using Sulfinert®-treated components for sampling and storing organo-sulfur compounds

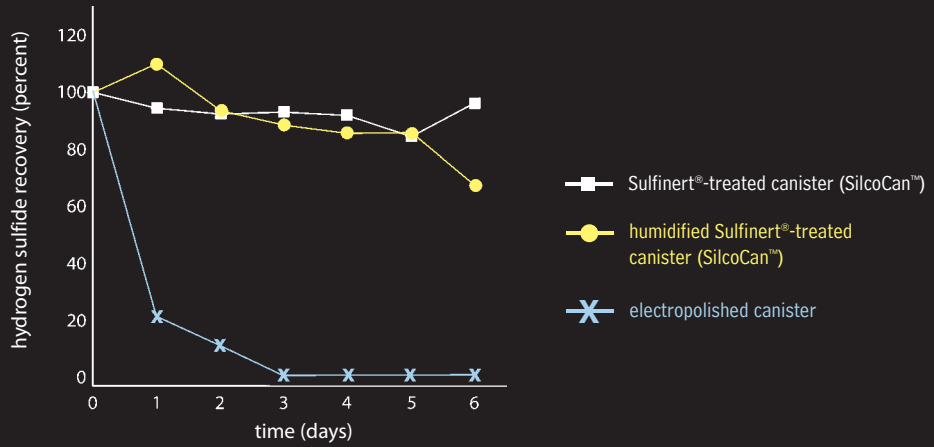
Prevent surface interactions with reactive organo-sulfur compounds at parts-per-billion levels.

Refineries and petrochemical plants use Sulfinert®-treated components for sampling, and for transferring sample streams. Natural gas and liquid propane gas manufacturers and transfer companies rely on Sulfinert®-treated systems to accurately quantify sulfur-containing odorants in natural and liquid propane gas streams. Sulfinert®-treated sampling equipment is specified in International Society of Beverage Technologists methods for determining sulfur impurities in beverage grade carbon dioxide. (ISBT procedure 1.0)

A wide variety of Sulfinert®-treated items are available from stock, including tubing, fittings, sample cylinders, valves and sampling components. If you have other requirements, please see Custom Coating Services on page 32.

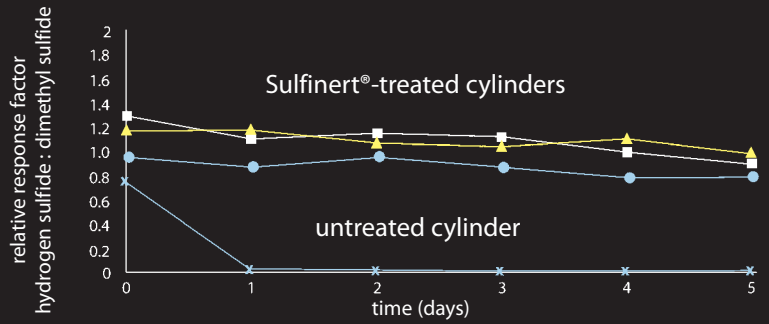
The Ideal Substrate for Holding and Transferring Reactive Sulfur Compounds

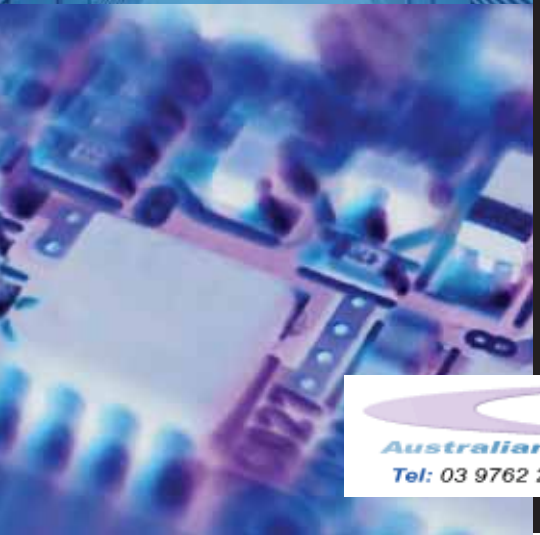
Sulfinert®-treated sample vessel outperforms electropolished stainless steel under dry and humid sampling conditions.



Excellent Long-Term Stability of Sulfur Compounds

Sulfinert®-treated sample cylinders show good recovery of sulfur compounds at 17ppbv. Untreated cylinders exhibit complete loss within 1 day.





Purity Control

In many purity-critical applications the potential for contamination created by contact of the process stream with sample transfer components such as tubing, fittings, and valves is a major concern. For example, the slightest contamination in gases used in manufacturing semiconductor devices can create high failure rates in end products.

Eliminate system component-process stream interactions.

Siltek™, Sulfinert®, or Silcosteel® treatment can eliminate interactions between process gases and transfer system components. Our extensive evaluations in the fields of passivation, corrosion resistance, and ultra-high vacuum show that these treatments eliminate outgassing of impurities into the sample stream and will not react with process stream components.

See our website for descriptions of the many Sulfinert®- and Silcosteel®-treated items available from stock. Refer to page 32 for information about custom treatment.

Coking Control

A major problem in hydrocarbon processing systems is the buildup of carbon on the surface of steel or stainless steel components—coking. Coking often is initiated by catalytic action of nickel or carbon impurities or additives in the steel used to construct the processing system components.

Restek chemists are working in conjunction with the Fuel Science Program at the Pennsylvania State University to quantify the effects of Siltek™ and Silcosteel® treatments on the formation of coke.[1] A Silcosteel®-treated system exhibits a 4-fold reduction in coke formation, compared to untreated stainless steel, but a modified Silcosteel® treatment, Silcosteel®-AC, can provide an 8-fold reduction. The Silcosteel®-AC or Silcosteel® layer forms a barrier between the hot hydrocarbon stream and the coking-susceptible steel substrate, and eliminates catalytic breakdown in the hydrocarbon stream. With the elimination of surface catalytic activity, carbon will not chemically adhere to the surface.

Reduce coking up to 8-fold

Current work indicates that the only mechanism of carbon formation in a Restek-treated system is the result of coking within the fluid phase. This material settles on the surface without adhering, and is easily removed by agitating the surface. Now, instead of "burning" out coke with oxygen at high temperatures, deposited carbon can simply be rinsed away.

Applications for Silcosteel®-AC coking control treatment include fuel injection nozzles, jet engine nozzles, engine valves, and engine cylinders.

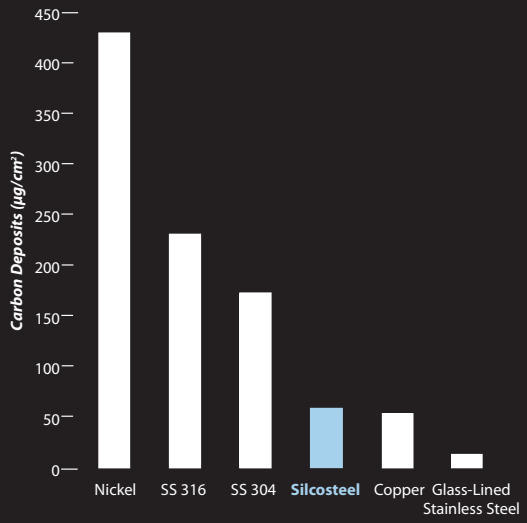
[1]Altin, O.; Venkataraman, A.; Eser, S. *Analysis of Solid Deposits from Thermal Stressing of a JP-8 Fuel on Different Surfaces in a Flow Reactor* Symposium on Structure of Jet Fuel V, Division of Petroleum Chemistry, Inc., 216th National Meeting, ACS, August 23-27, 1998).

Silcosteel®-AC treatment eliminates the need for "burning out" hydrocarbon processing equipment.

We continue to investigate other coatings specifically designed to reduce coking. The figures on the opposite page demonstrate the amount of coking occurring on various substrates. Silcosteel®-AC-treated 304 stainless steel shows dramatic reduction in coking vs. non-treated 304 stainless steel, and the table compares the performance of Silcosteel®-AC, Silcosteel®, and Sulfinert® to prototype treatments.

Carbon Build-up Tests

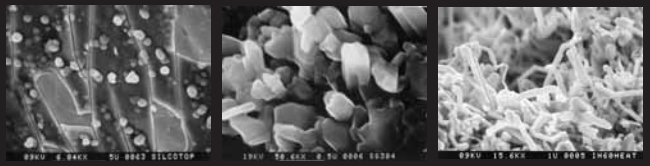
Carbon deposit from JP-8 fuel on various types of tubing (500°C, 500psi, 1cc/min. flow rate).



Silcosteel®-AC-treated 304 grade stainless steel components exhibit the greatest reduction in coking.

Surface	Carbon Buildup (µg/cm²)
Silcosteel®	15.4
Sulfinert®	11.9
Prototype B	7.8
Silcosteel®-AC	7.4

Silcosteel®-AC prevents catalytic formation of metal sulfides and filamentous carbon deposits. (JP-8 fuel stressed at 500°C, 500psi, for 5 hours.)



Silcosteel®-AC | 304 Stainless Steel | Competitor A

Corrosion Control

Corrosion currently costs the United States economy $276 billion per year[1] and costs the world economy even more. In acidic environments it is critical to engineer solutions to account for the depreciation of equipment caused by corrosion. Current commercial solutions that address corrosion are specialized alloys, such as Inconel®, Monel® and Hastelloy®—or coatings.

We developed Silcosteel®-CR treatment to protect equipment exposed to hydrochloric acid, nitric acid, sulfuric acid, or marine environments. Silcosteel®-CR treatment upgrades the corrosion resistance of 300-grade stainless steels by an order of magnitude.

Silcosteel®-CR, an effective, durable solution at lower cost than specialty alloys.

An advantage of Silcosteel®-CR treatment over super-alloy solutions is cost. Many of the high nickel super-alloys, such as Inconel®, Monel® and Hastelloy® are expensive and machining costs are higher for these soft materials than for 300-grade stainless steels.

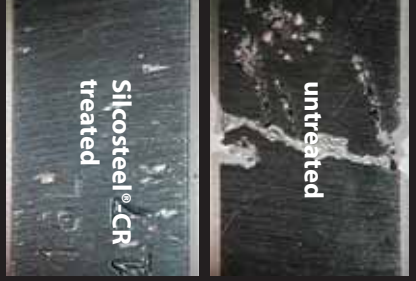
Silcosteel®-CR treatment also offers major advantages over traditional coatings. Our chemical vapor deposition process incorporates the treatment into the stainless steel lattice. Traditional overlay coatings rely primarily on primers or surface tension to remain in contact. The Silcosteel®-CR process eliminates delamination, a common problem with overlay coatings.

[1] *Corrosion Costs and Preventive Strategies in the United States* U.S. Department of Transportation Federal Highway Administration, Publication No. FHWA-RD-01-156.

Silcosteel®-CR treatment protects equipment exposed to hydrochloric acid, nitric acid, sulfuric acid, or marine environments.

A Silcosteel®-CR layer is both durable and flexible. The layer builds from many starting points on the steel surface. Repeated overlaying as the deposition grows on the surface creates a dense, impenetrable layer. This layering process also creates flexibility—treated components can be worked into place without cracking, chipping, or otherwise damaging the layer.

A selection of Silcosteel®-CR treated fittings and tubing are available from stock. For custom treatment, refer to Custom Coating Services on page 32.



Pitting and Crevice Corrosion Tests

In studies of exposure to 6% w/w ferric chloride, Silcosteel®-CR treated 316L stainless steel outperformed untreated 316L steel by a factor of 10. This test was conducted per ASTM G48, Method B.

1000 Hour Salt Spray Tests

Silcosteel®-CR treated 316L steel showed no sign of attack after 1000 hours of salt spray exposure , per ASTM B117.

Condensing Humidity Tests

Silcosteel®-CR treated 316L steel withstands environments simulating outdoor exposure, per ASTM D 4585.

Cyclic Polarization Electrochemical Tests

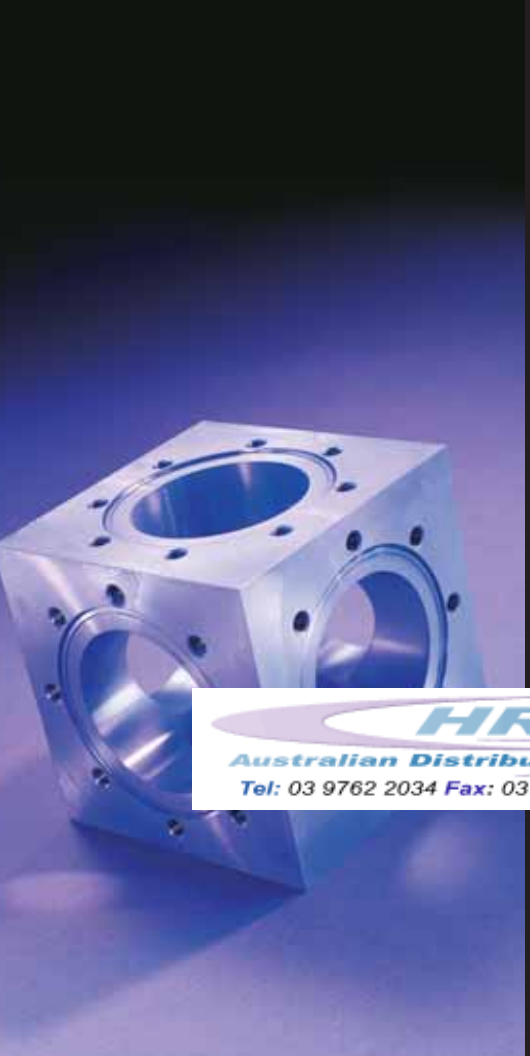
Electrochemical corrosion testing of Silcosteel®-CR treated 316L stainless steel yielded the following corrosion and pitting potentials in neutral and acidic conditions, per ASTM G61.

Breakdown or pitting potential, E_b, in millivolts.

Neutral Solution	Silcosteel®-CR	Bare Steel
100ppm chloride	>3000	674
3000ppm chloride	1460	370
5000ppm chloride	1590	285
Acidic Solution (1N H_2SO_4)		
100ppm chloride	1128	580
3000ppm chloride	927	370
5000ppm chloride	983	563

Corrosion of Silcosteel®-CR treated 316L stainless steel versus bare stainless steel at 3000ppm Cl^- concentration.

Neutral Solution	Silcosteel®-CR	Bare Steel	Improvement
Corrosion Rate, mpy	0.0009	0.04	50X
Breakdown Potential, E_b	1460	370	
Acidic Solution (1N H_2SO_4)			
Corrosion Rate, mpy	0.05	0.83	10X
Breakdown Potential, E_b	927	370	



Ultra-High Vacuum

R&D Magazine recognized Silcosteel®-UHV as one of the 100 most technologically significant products introduced in 2003.

Ultra-high vacuum (UHV) environments are critical for many analytical instruments and particle accelerators used to analyze the properties of materials and atoms. UHV systems are characterized as requiring a vacuum of 10^{-9} torr or better. At this level of vacuum even steel components outgas large quantities of moisture. Massive pumping systems are needed to remove molecules as they are generated.

Dramatically reduce outgassing and pump-down time

We developed Silcosteel®-UHV treatment specifically to significantly reduce outgassing by steel components in UHV systems. A Silcosteel®-UHV layer over the steel surface is a barrier that keeps moisture isolated from the UHV environment. The Silcosteel®-UHV layer does not liberate any atmosphere of its own. The figures on page 31 demonstrate the superior evacuation profile sustained by using Silcosteel®-UHV-treated components vs. non-treated components in a UHV assembly. Clearly, Silcosteel®-UHV treatment makes it possible to maintain a UHV environment with less pumping capacity.

Further, when not under vacuum, the Silcosteel®-UHV surface is far less likely to accrue a coating of water and other airborne molecules than is a non-treated surface. This greatly reduces the length of time required to re-attain a UHV environment.

Silcosteel®-UHV treatment is available as a custom service. For information, refer to Custom Coating Services on page 32.

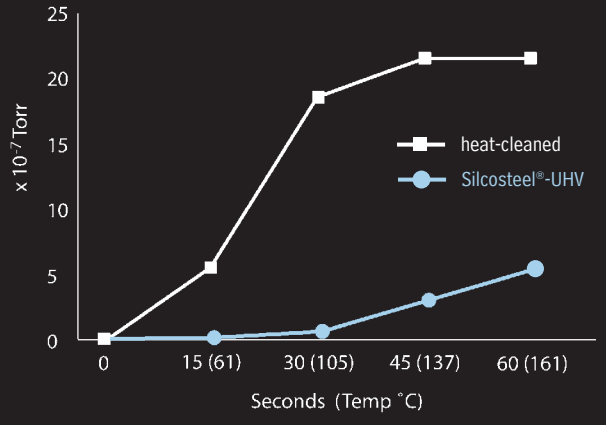
Maintain Seal Integrity

The durable Silcosteel®-UHV layer will withstand the sealing requirements of UHV, maintaining knife edge integrity.

Significantly Reduce Pump-Down Time

Silcosteel®-UHV-treated vacuum system components show significantly less outgassing, compared to heat-cleaned components.

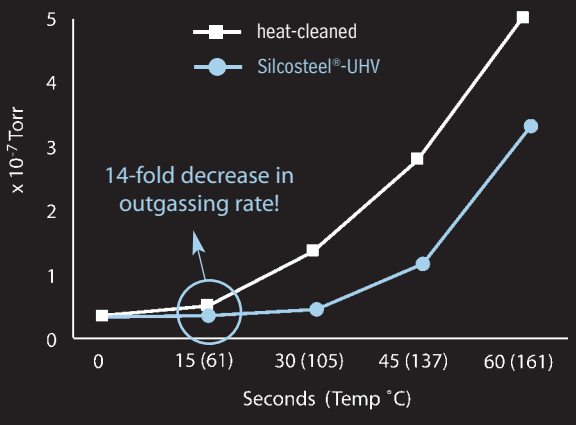
Pressure Increase with Heat After 1 hr Under Vacuum

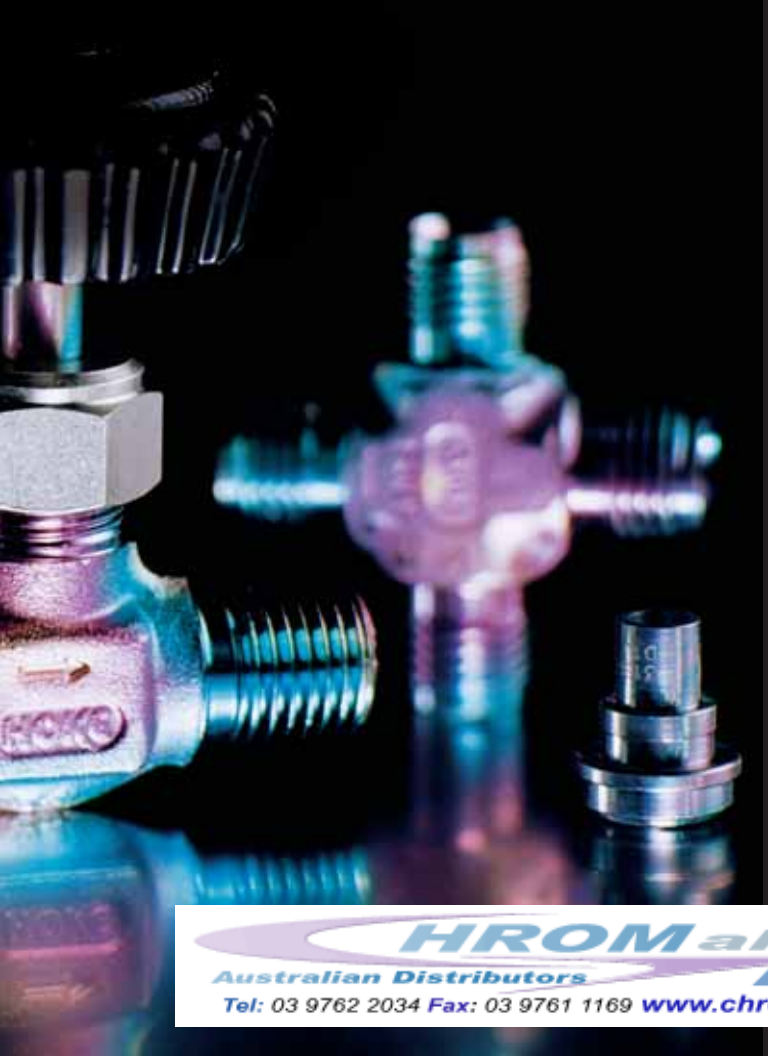


Significantly Reduce Outgassing

After 10hr under vacuum, Silcosteel®-UHV-treated components continue to show significantly less outgassing. Note change in y-axis scale compared to figure at left.

Pressure Increase with Heat After 10 hr Under Vacuum





Custom Coating Services

We will work with you to meet your surface treatment needs. Please contact us to discuss unique requirements. See next page for obtaining a quote for custom treatment.

What can we treat?

Parts that can tolerate a sustained temperature of 400ºC, with pressurization/evacuation.

Substrates	stainless steels, steels, steel alloys, high-performance nickel alloys, glass, ceramics
Parts	fittings, valves, frits, custom parts with complex topography (inside and out)
	largest vessel: 1ft. ID x 4ft. cylinder w/ 10in. opening (30.5 x 122cm, 25.4cm opening)
Tubing	0.004in. to 0.5in. ID (0.10–12.7mm); continuous lengths to 2000+ ft. / 600+ meters*

What can't we treat?

aluminum (heat-dependent), copper, brass, gold- or silver-plated components, magnesium, nickel (we can treat most high-performance alloys); elastomers

Process

Receive	Document receipt of items—first customer contact
Clean	standard: caustic ultrasonic bath, two systems; custom: as needed or requested
Process	silicon-based materials, chemical vapor deposition—vacuum, 400ºC
Clean	standard: ultrasonic bath; custom: as needed or requested
Ship	document process—second customer contact—pack and ship

*Please allow 6 inches of extra tubing on each end if the final tubing length is critical.

To obtain a quote for custom surface treatment, please follow these instructions:

1. Visit the home page of our website: www.restekcoatings.com
   - Navigate to the custom treatment request forms.
   - Choose the treatment form you need and print it.

2. Check the box next to the description matching that of the items to be treated. Indicate quantity to be sent for treatment. If the item cannot be matched with any of the listed options:
   - Prepare a dimensional drawing or scaled photograph.
   - Indicate composition of item (stainless steel, alloy type, etc.).

3. Initial the disclaimer on the request form. This initialed disclaimer is required before we can begin to process your items.

4. Fax the completed form to Restek Corporation at 814-353-1309 or contact your local Restek representative.

Quotations will be prepared and returned within 24 hours of our receipt.

If you accept our quote, contact Restek Corporation for an authorization number. This number is required for any package shipped to Restek. Any package received without an authorization number will be returned to the sender.

Turnaround time for most custom treated items is 10 days or less.

2-Touch™ Program

The Restek Performance Coatings Division has developed the 2-Touch™ Program to ensure that customers are kept up to date with progress of their parts during the treatment process. The first touch will be contact on receipt of your job, to discuss questions or anticipate concerns that could arise during processing, and to give you a completion date. The second touch will be at the completion of the treatment process, to notify you of the results and give you an option to update return shipment information.

Many of our current customers have found this service very helpful, and we will continue to adapt the 2-Touch™ Program to meet the needs of all customers.

Other highlights of the 2-Touch™ Program:

- Each job is tracked and recorded, using a unique lot number. Digital photos are taken of all items in each job at arrival and prior to return shipment. These records will be available to you, should you ever have need of them.
- Each item is individually packaged for maximum protection.
- Treatment certifications are supplied for each job.

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