

# Silcosteel®-CR

Improve corrosion resistance by tenfold, or more.  
*Protect your investment.*

- Prolong component lifetimes.
- Reduce preventive maintenance.
- Reduce contamination caused by corrosion.
- Eliminate the need for costly super alloys.

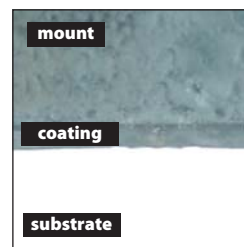
In acidic environments it is critical to engineer solutions to protect equipment from corrosion. Current commercial solutions that address corrosion are specialized alloys (e.g., Inconel®, Monel®, Hastelloy®)—or coatings.

Coatings often are employed as acid-resistant barriers between the corrosive environment and the equipment. Silcosteel®-CR surface treatment offers major advantages over traditional coatings: our chemical vapor deposition process incorporates the coating into the stainless steel lattice, eliminating delamination and blistering, common problems with traditional overlay coatings which rely primarily on primers or surface tension to remain in contact. We developed the Silcosteel®-CR treatment specifically to protect equipment exposed to hydrochloric acid, nitric acid, sulfuric acid, or marine environments. A Silcosteel®-CR treatment upgrades the corrosion resistance of 300-grade stainless steels by greater than an order of magnitude.

Silcosteel®-CR is a proprietary (patent pending), multilayer silicon, chemical vapor-deposited (CVD) coating, specifically designed to improve corrosion resistance of steel, stainless steel, alloys, glass, and ceramics. The unique non line-of-sight CVD process produces a flexible amorphous silicon layer that diffuses into the metal lattice. The layer will conform to the most intricate surface while maintaining high dimensional tolerances. Silcosteel®-CR will deform with tubing surfaces, allowing leak-free seals or radius bends.

Figure 1 shows a cross-section optical micrograph of a Silcosteel®-CR treated coupon having a surface roughness average of 16 micro inches. The dense, well-bonded layer will afford reliable protection from acidic media. Several standardized corrosion testing protocols have been performed on the Silcosteel®-CR treatment. Following are the results of some of these tests.

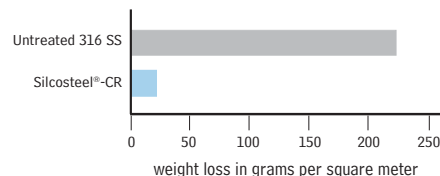
**Figure 1** The Silcosteel®-CR coating is a well-bonded, dense layer designed to protect the substrate from attack by acids.



### Independent Laboratory Testing

Corrosion testing of Silcosteel®-CR treated 316L stainless steel and untreated 316L steel according to ASTM G 48, Method B2 (72-hour ferric chloride pitting and crevice corrosion testing), shows corrosion of the treated stainless steel is reduced by an order of magnitude, as measured by weight loss. Figure 2 summarizes the results of this experiment. Silcosteel®-CR treated 316L stainless steel samples exhibited an order of magnitude less corrosion, compared to bare samples. As seen in Figure 3, Silcosteel®-CR treated coupons exhibited no crevice corrosion, while untreated coupons exhibited severe crevice corrosion. Silcosteel®-CR treated coupons experienced only slight pitting corrosion during this aggressive test.

**Figure 2** Silcosteel®-CR treated stainless steel outperforms uncoated metal by an order of magnitude (ASTM G 48, Method B).



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# Silcosteel®-CR Fast Facts

**Figure 3** Silcosteel®-CR treated 316L stainless steel coupons show no crevice corrosion and only slight pitting corrosion.



Silcosteel®-CR treated

**Figure 4** Bare 316L stainless steel coupons exhibit severe crevice corrosion.



untreated

## Cyclic Polarization Electrochemical Corrosion Testing of Silcosteel®-CR Treated 316L Stainless Steel Coupons and Bare 316L and Bare 304 Stainless Steel Coupons, by ASTM G 61

Samples were tested in accordance with ASTM G 61 in acidic and neutral aqueous solutions, at 23°C, at three chloride ion (Cl<sup>-</sup>) levels. Tables 1 and 2 summarize the test results: Silcosteel®-CR treated 316L stainless steel coupons outperformed bare 316L stainless steel by a factor of approximately 50 in neutral chloride solutions, and by approximately 10 in acidic chloride solutions. At a chloride concentration of 3000ppm, Silcosteel®-CR treated 316L stainless steel coupons outperformed 304 stainless steel coupons by a factor of approximately 65 in neutral solutions and by approximately 20 in acidic solutions. Table 3 summarizes the test results for Silcosteel®-CR treated 316L stainless steel and bare 304 stainless steel. Table 4 summarizes the corrosion potential, E<sub>c</sub>, for Silcosteel®-CR treated 316L stainless steel.

**Table 1** Silcosteel®-CR treatment greatly reduces corrosion rates in chloride solutions. (Corrosion rate in mpy (mil per year) determined by electrochemical testing.)

	Silcosteel®-CR	Bare Steel (316L)	Improvement
<b>Neutral Solution</b>			
100ppm chloride	0.0006	0.03	49X
3000ppm chloride	0.0009	0.03	32X
5000ppm chloride	0.001	0.03	29X
<b>Acidic Solution (1N H<sub>2</sub>SO<sub>4</sub>)</b>			
100ppm chloride	0.05	0.45	8X
3000ppm chloride	0.05	0.83	16X
5000ppm chloride	0.07	0.84	11X

**Table 2** Breakdown or pitting potential, E<sub>b</sub>, in millivolts, determined by electrochemical testing.

	Silcosteel®-CR	Bare Steel (316L)
<b>Neutral Solution</b>		
100ppm chloride	>3000	674
3000ppm chloride	1460	370
5000ppm chloride	1590	285
<b>Acidic Solution (1N H<sub>2</sub>SO<sub>4</sub>)</b>		
100ppm chloride	1128	580
3000ppm chloride	927	370
5000ppm chloride	983	563

**Table 3** Corrosion of Silcosteel®-CR treated 316L stainless steel versus bare 304 stainless steel at 3000ppm Cl<sup>-</sup> concentration.

	Silcosteel®-CR	Bare Steel (304)	Improvement
<b>Neutral Solution</b>			
Corrosion Rate, mpy	0.0009	0.06	66X
Breakdown Potential, E <sub>b</sub>	1460	361	
<b>Acidic Solution (1N H<sub>2</sub>SO<sub>4</sub>)</b>			
Corrosion Rate, mpy	0.05	1.14	22X
Breakdown Potential, E <sub>b</sub>	927	587	

**Table 4** Corrosion potential, E<sub>c</sub>, in millivolts, for Silcosteel®-CR treated 316L stainless steel.

	E <sub>c</sub>
<b>Neutral Solution</b>	
100ppm chloride	-188mV
3000ppm chloride	-418mV
5000ppm chloride	-420mV
<b>Acidic Solution (1N H<sub>2</sub>SO<sub>4</sub>)</b>	
100ppm chloride	-782mV
3000ppm chloride	-843mV
5000ppm chloride	-863mV

## 4000 Hour Salt Spray Testing (ASTM B 117) of Silcosteel®-CR Treated 316L Stainless Steel Coupons and Bare Coupons

ASTM B 117 (*Practice of Operating Salt Spray (Fog) Apparatus*) was run for a total of 4000 hours. Three Silcosteel®-CR treated 316L stainless steel coupons and 3 bare coupons were tested side by side. The Silcosteel®-CR treated coupons showed no signs of bleeding, rusting or pitting corrosion. The bare samples exhibited light surface rusting but no signs of pitting. Figure 5 shows a Silcosteel®-CR treated sample and a bare steel sample after salt spray testing.

**Figure 5** Silcosteel®-CR treated 316L stainless steel coupons show no corrosion as a result of salt spray testing; bare coupons show rusting at aperture.\*



\*Color variations on the Silcosteel®-CR treated coupon are due to light refraction by the treatment layer.



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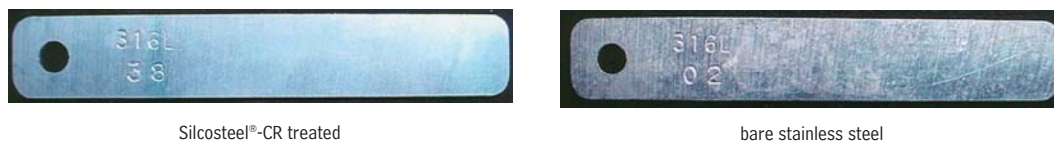


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**Condensing Humidity Testing (ASTM D 4585) of Silcosteel®-CR Treated 316L Stainless Steel Coupons and Bare Coupons** ASTM D 4585 (*Practice for Testing the Water Resistance of Coatings, Using Controlled Condensation*) was run for a total of 1000 hours. Three Silcosteel®-CR treated 316L stainless steel coupons and 3 bare coupons were tested side by side. The Silcosteel®-CR treated coupons showed no signs of bleeding, rusting, or pitting corrosion. The bare samples exhibited a very light surface oxide film as a result of exposure. Figure 6 is a photograph of a Silcosteel®-CR treated sample and a bare steel sample after testing.

**Figure 6** Silcosteel®-CR treated 316L stainless steel coupons show no impact of water exposure; bare coupons exhibit a light oxide layer.



### Increase profit with Silcosteel®-CR

Figure 7, a comparison of lifetime costs in a typical process system, shows Silcosteel®-CR treatment can reduce the overall lifetime cost of the system by hundreds of thousands of dollars. While the initial cost of an unprotected stainless steel system is lower than that of a comparable Silcosteel®-CR system, the overall lifetime cost, considering replacement cost due to corrosion, is nearly double that of a Silcosteel®-CR treated system. Conversely, high performance alloy systems offer superlative corrosion performance, but the initial material cost can be up to six times that of a comparable stainless steel system.

### Conclusion

Test data show that Silcosteel®-CR treatment is effective in extending the corrosion resistance of stainless steel process systems while reducing overall system maintenance cost (Figure 7). Because Silcosteel®-CR treatment can be applied to a majority of existing process components, process equipment life is extended without significant re-engineering.

### About Us

Restek's involvement in coatings began in 1987. The focus of our initial work was to produce a coating on stainless steel that was inert to low-level reactive organic compounds, such as explosives and volatile organic compounds (VOCs). Silcosteel® treated tubing currently is used for construction of analytical testing equipment by all major manufacturers of gas chromatography sampling and testing equipment. Since this initial project, Restek's coatings experts have developed a family of coatings to address other specific needs and thereby enhance the performance of system components. In brief, these coatings are:

- **Silcosteel®**—A general purpose passivation layer for steel and stainless steel. U.S. Patent 6,511,760.
- **Silcosteel®-CR**—A corrosion resistant layer that increases the lifetime of system components in acidic environments containing hydrochloric, nitric, or sulfuric acid. U.S. Patent 7,070,833.
- **Silcosteel®-UHV**—Used to reduce outgassing by components of ultra-high vacuum systems. U.S. Patent 7,070,833.
- **Silcosteel®-AC**—Dramatically reduces carbon buildup on stainless steel components. U.S. Patent 6,444,326.
- **Siltek™**—Provides the ultimate passivation of coated components, from glass to high nickel alloys of steel. U.S. Patent 6,444,326.
- **Sulfiner™**—A required coating on metal components when analyzing for parts-per-billion levels of organo-sulfur compounds. U.S. Patent 6,444,326.



Restek's headquarters are in Bellefonte, Pennsylvania, USA, with distributors and representatives in over 80 countries.

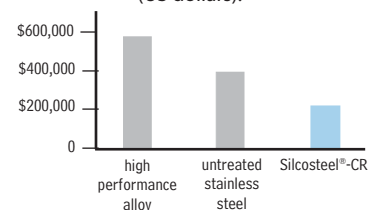


Marty Higgins, Joe Miller, Mark Eckley, Randy Emel, Kathy Emel, Jeff Corman, Gary Barone, David Smith, David Facey, Carrie Sprout, Barry Spicer, Bob King (not pictured: Jim Mattzela and Randy Sampsell)

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**10 days or less!**  
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Coatings Team.

## Silcosteel®-CR Fast Facts

**Figure 7** Silcosteel®-CR demonstrates significant cost savings in gas delivery systems, compared to untreated stainless steel or alloys (US dollars).



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# Silcosteel®-CR Fast Facts



We offer a wide variety of  
**Silcosteel®-CR-treated fittings**  
and custom treatment. For information and  
ordering, call us or visit us online.

## Silcosteel®-CR Treated Coiled Electropolished 316L Grade Stainless Steel Tubing

- Exceptional inertness.
- Improved reliability and reproducibility; longer lifetime.
- Use with treated fittings for the most inert sample pathway available.



*Top:* electropolished finish, surface roughness average number: 5-10.

*Bottom:* conventional finish, surface roughness average number: approx. 23-27.

ID	OD	cat.#
0.085"	1/8"	22536
0.180"	1/4"	22537

## Coiled Silcosteel®-CR -Treated Seamless 316L Stainless Steel Tubing

ID	OD	cat.#
0.055" (1.40mm)	1/8" (3.18mm)*	22896
0.180" (4.57mm)	1/4" (6.35mm)*	22897

Tubing priced per foot by length.

For a complete listing of stock treated tubing,  
visit us online.



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