Review of Silicon Coatings Capabilities and Applications

SilcoTek Corporation
112 Benner Circle
Bellefonte, PA 16823
814-353-1778
www.SilcoTek.com

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Overview

- Background:
  - About silicon coatings, CVD process and capabilities
- Comparative Testing, Benefits, Applications
    - Inertness and Sulfur
    - Corrosion resistance
    - Anti-coking
    - Purity/Ultra high vacuum
- Questions

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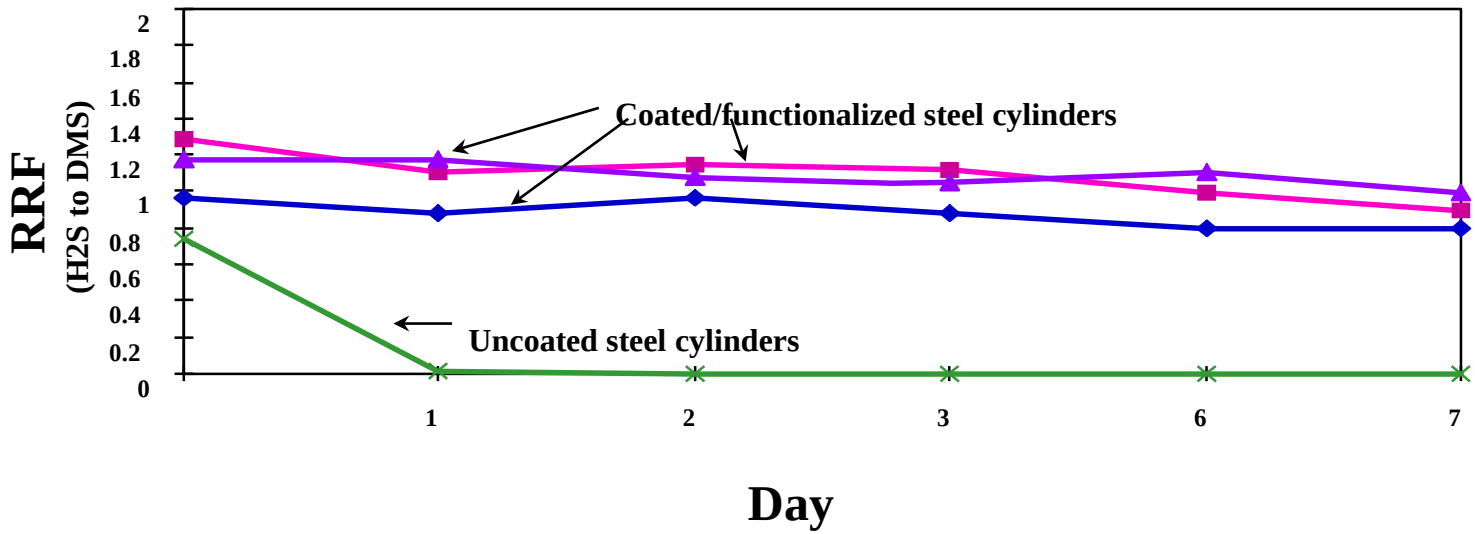
Why use coatings?

- Reduce loss of active compounds
  - Avoid false negatives
  - Sulfur compounds quickly lost without coatings
  - Improved sample transfer
  - Sample stable from field to lab
  - Avoid loss of sample due to adsorption
    - Sulfur
    - Mercury
  - Immediate response during process changes
  - Creates savings when used in feedback monitors
  - Reduces moisture contamination effects

No Loss during storage!

- Reduces adsorption effects
- Improves analytical reliability
- Faster cycle times and
- increased accuracy
  - 17ppbv H_2S Containment in 500ml Cylinders



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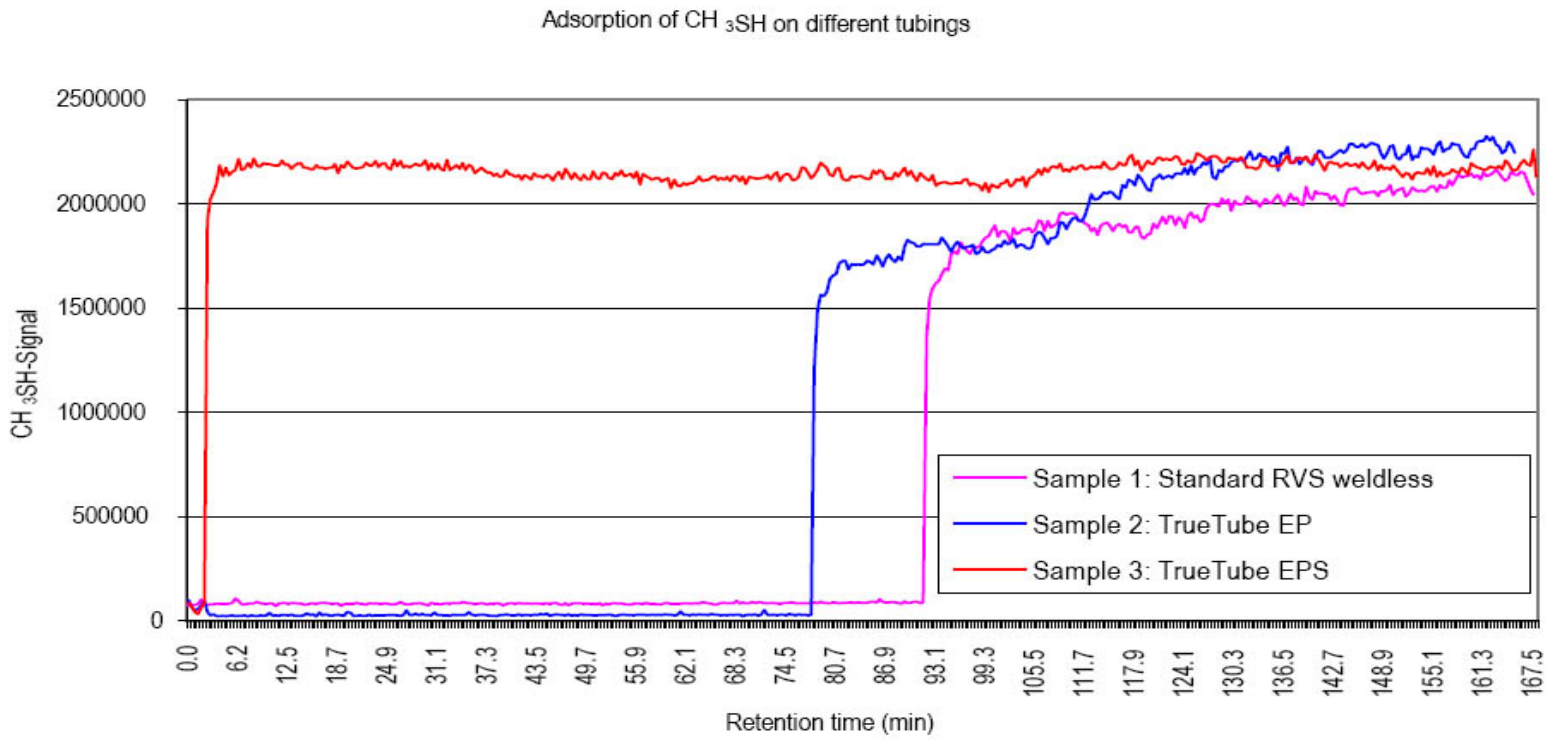
No transfer Loss!

Reduce sample adsorption by 98%
Improve Process Response
Improve Yield



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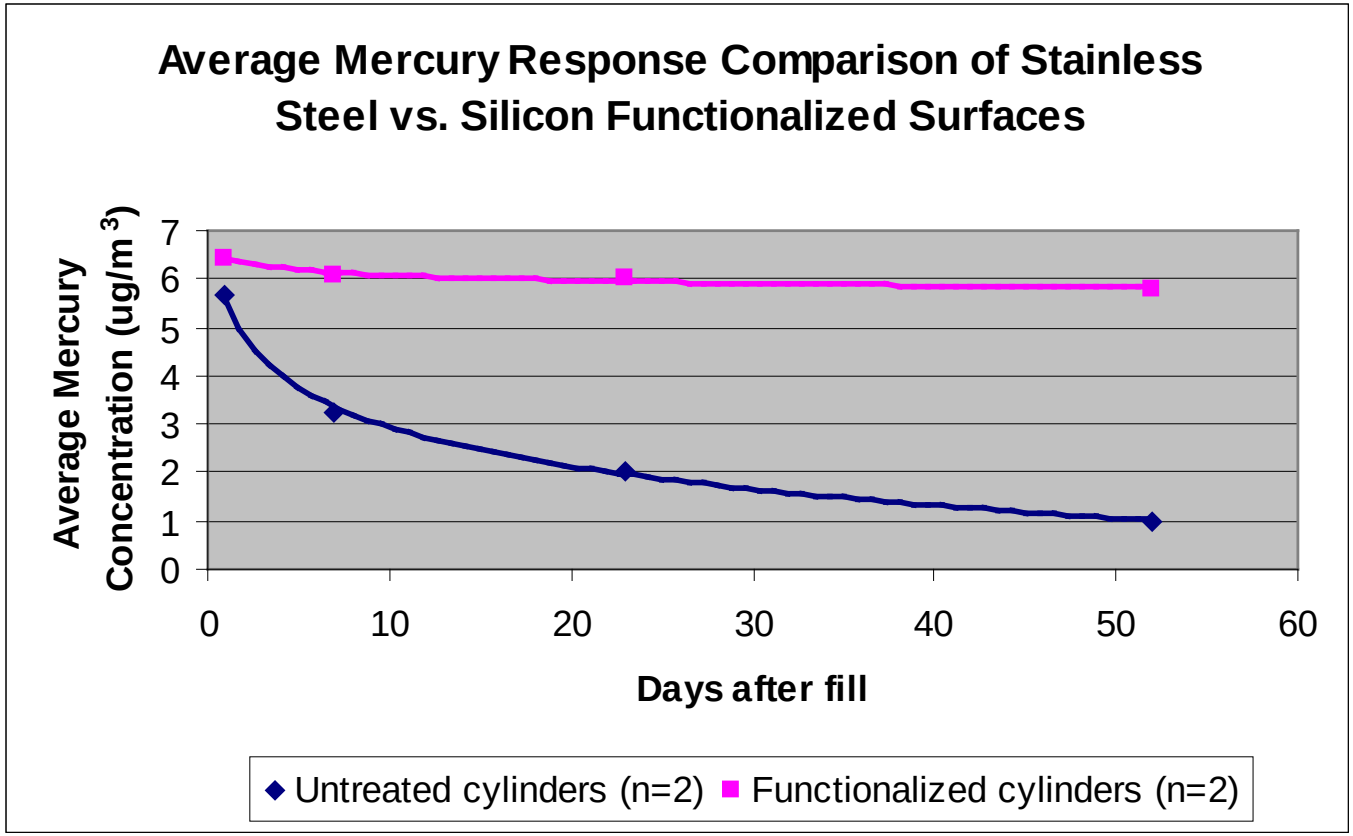
Mercury stable during storage!



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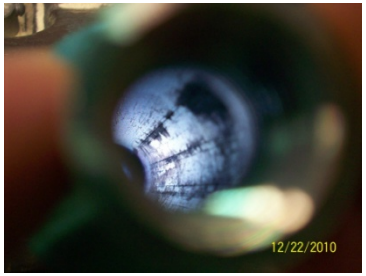
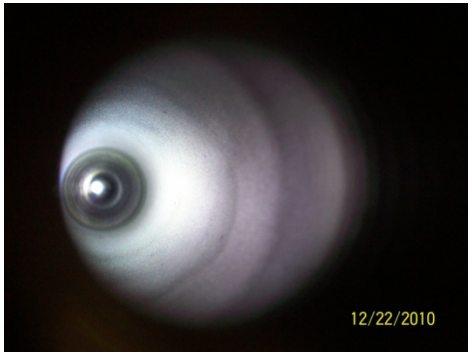
SilcoNert 2000 Advantages

- Most inert coating available





- High Temperature
- Durable/flexible/high tolerance
- Enable testing in rugged environment
- Allows user to modify surface without redesign/remanufacture

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SilcoNert 2000 & Dursan Applications

Sulfur contaminants, CO2	NOx and SOx from coal plants
Sulfur emissions, refinery flares	Mercury emissions, coal and gas
Ethylene/propylene feedstock testing	Water quality testing, headspace + purge and trap
Exhaust, stack emissions, ammonia	Toxic organics, whole air monitoring
Defense security, chemical warfare agents, explosives	Low moisture sampling and control
GC testing of active compounds	Oil and gas, downhole, transport and refinery sampling

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Why use coatings?

- Corrosion resistance
  - Prolong component life
    - Salt water environments (platforms)
    - Chemical process industry
    - Refining
  - Save money by avoiding use of chrome/moly or high-nickel alloys for:
    - Chloride exposure
    - Produced water
    - Instrumentation
  - Some coatings offer both corrosion and inertness

2 Corrosion Resistant Coatings

- Silcolloy 1000
  - Silicon, up to ½ um thick
  - Semiconductor, purity

- Dursan
  - Silicon, carbon, oxygen, 1/2um + thick
  - High durability, greater corrosion resistance

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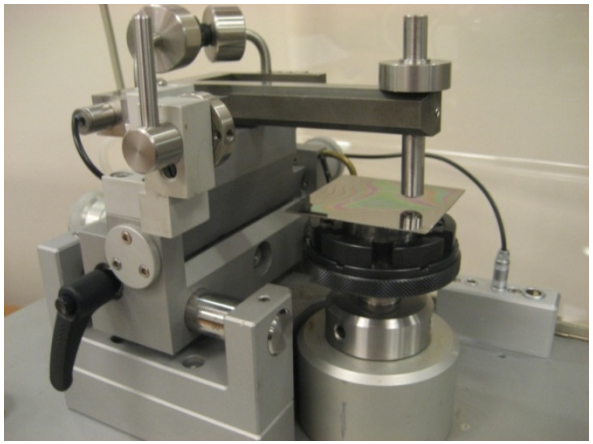
Wear Resistance Comparison

Pin on Disc; 2.0N	316 SS	Silicon	Carboxysilane
Wear rate ($x10^{-5} mm^3/N\ m$)	13.810	15.344	6.129
Improvement Factor over Stainless Steel	---	0.9 X	2 X

- CSM Instruments
- Tribometer 18-343 used to measure surface wear resistance



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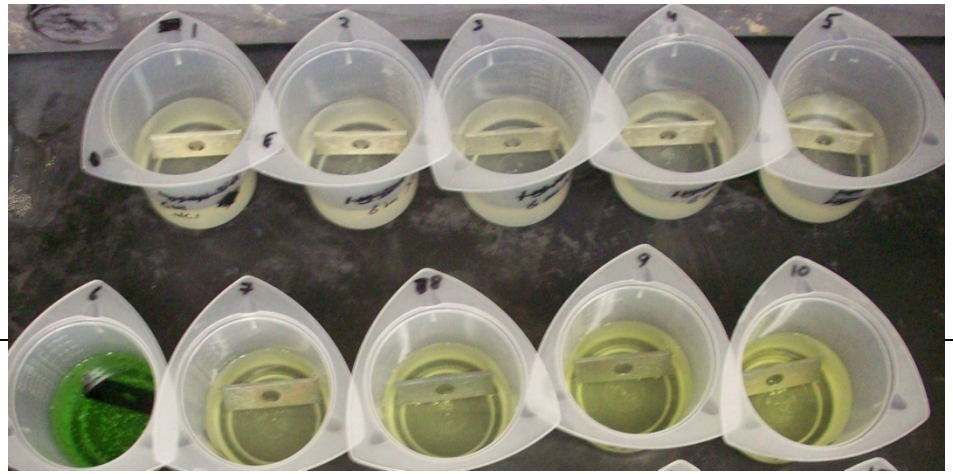
Acid Corrosion Resistance

- ***ASTM G31 Guidelines: <u>6M HCl</u>; 24hr; 23ºC***

	316L SS	Silcolloy	Dursan
MPY	181.98	4.32	0.44
Improvement Factor over 316L stainless	---	42	411



Comparative Corrosion Resistance

- *10% H_2SO_4; 24hr; 22ºC*

ASTM G31	316L SS	Silcolloy	Dursan
MPY	22.35	2.52	2.42
Improvement Factor over 316L stainless	---	8.9	9.9

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Base Corrosion Resistance

- ***ASTM G31 Guidelines: 1M KOH; 24hr; 22ºC***

	316L SS	Silcolloy	Dursan
MPY	**0**	**3.40**	**0.01**
Improvement Factor Over a-Silicon	**--**	**--**	**261**

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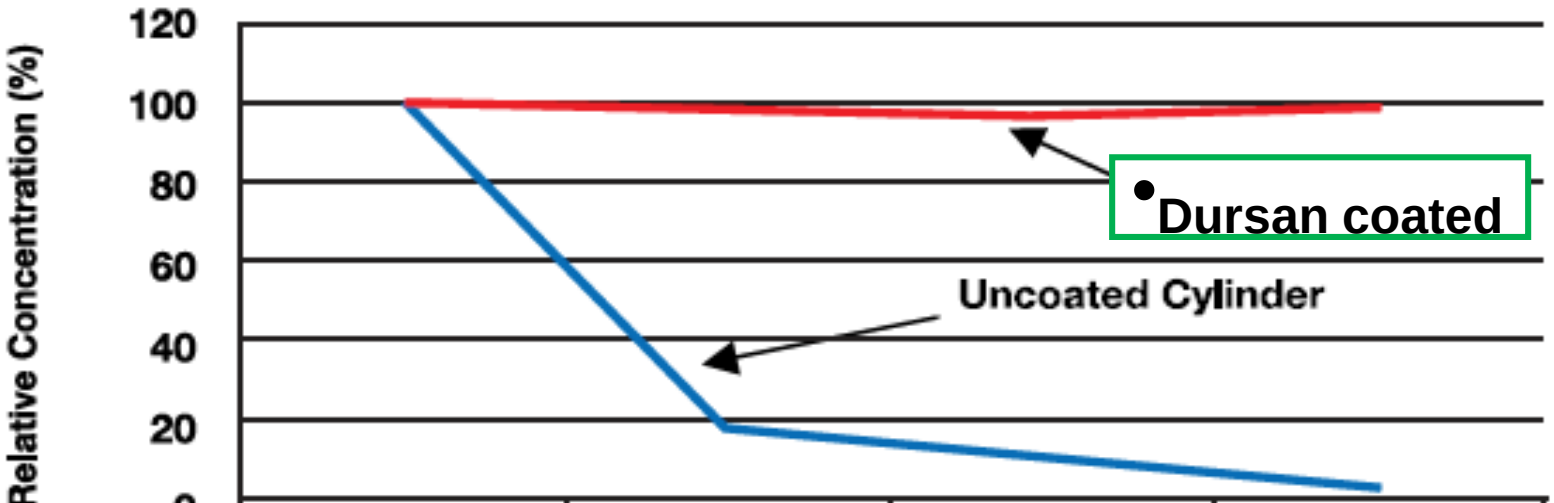
Chemical Inertness

H_2S Stability: Dursan vs. Stainless Steel

50ppmv, 300cc cylinder



	0:00	25 hours	50 hours	75 hours
Stainless Steel	100	19	10	4
Dursan	100	98	96.6	98.3

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Hydrophobic Properties

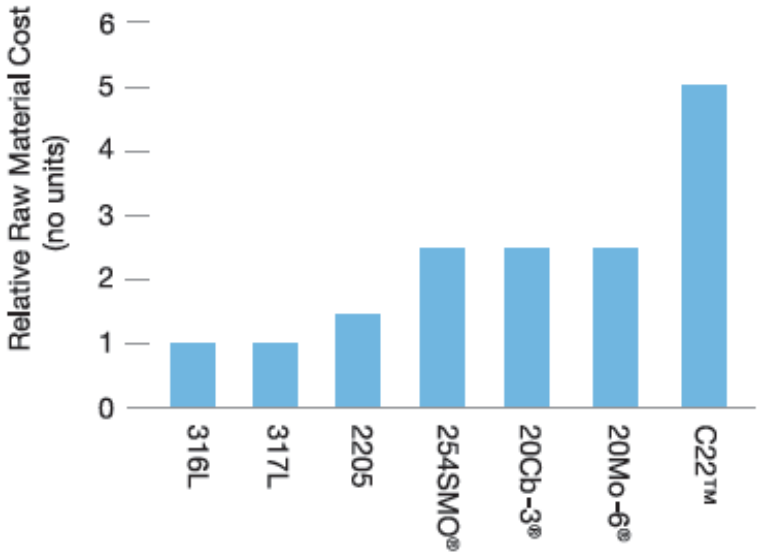
- Krüss K100 Tensiometer
- Testing on
- 304 SS
- ¼” OD tubing

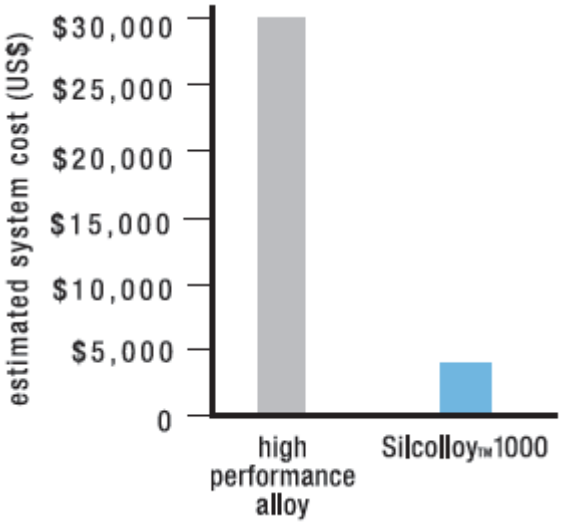
	304 SS	Silcolloy 1000	SilcoNert 2000	Dursan	PTFE Plate
Advancing	36.0	53.6	87.3	105.5	125.4
Receding	5.3	19.6	51.5	85.3	84

304 SS SN 1000 SN 2000 Dursan

Materials Cost Comparison

80% estimated life cycle cost savings: a-Si vs. HP Alloy





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Dursan Advantages

- Significantly improves material performance beyond exotic alloys
- Improve SS acidic and basic corrosion resistance
- 2X improvement in wear resistance
- Inert, non reactive, non-adsorptive
- Withstands temperature up to 450° C
- Hydrophobicity and oleophobicity similar to Teflon surface

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Coating Advantages

- Longer Life:
  - Extend lifetimes of equipment exposed to corrosive environments
- Low Cost Material Option
- Protection:
  - Protection of high value equipment
- Inert:
  - Provide enhanced corrosion resistance to analytical equipment
  - Maintain inert sample pathway
  - More inert than Inconel, Hastelloy, or glass. Ideal for 10ppm levels or higher
- High Temperature:
  - High temperature stability up to 1000°C

Silcolloy & Dursan Applications

- ❑Process streams
- ❑Process sampling/Refinery
- ❑Continuous Emissions Monitoring Equipment
- ❑Automotive Exhaust
- ❑Semiconductor corrosion (Silcolloy)
- ❑Fasteners in Offshore/Marine, Drill bits
- ❑Off-shore drilling platform equipment
- ❑Produced water management

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Why use coatings?

- Reduce coking and carbon fouling
- Extend maintenance cycle
- Improve equipment efficiency
- Reduce emissions
- Prevent system failures due to fouling

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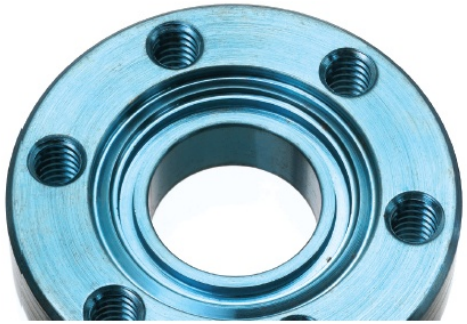
Why use coatings?

- High Purity



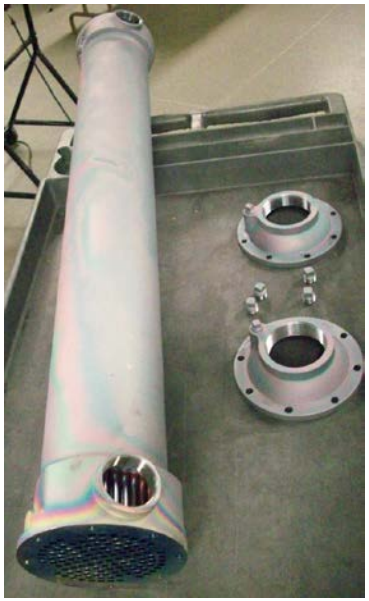
  - Reduce system contamination
  - Reduce moisture effects
  - Eliminate ion contamination
  - Reduce vacuum pump down time

Conclusion

- Coatings are available for a wide range of applications

- Optimize based on desired property
    - Inertness
    - Corrosion Resistance
    - Anti-Coking
    - Purity

- Ultimate benefit is superior performance
    - Analytical results
    - Extend life
    - Reduce labor and capital cost
    - Improve efficiency
    - Optimize material selection and cost performance



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