Application of TrueTube™ in Analytical Measurement

October 2004

Purpose

This report discusses the results of the following tests:

- *"Testing Electropolished and Electropolished Silica Steel Coated Tubing on Adsorption of Methymercaptane"* March 2004 Shell Research and Technology Centre
- *"Study of 6N HCl Corrosion on Commercial 316 SS, Hastelloy C-22 and TrueTube Variants"* April 2004 Restek Corporation & Cardinal UHP
- *"Relative Response Time of TrueTube when Measuring Moisture Content in a Sample Stream"* May 2004 Haritec Scientific & Engineering Support

Proposals are made for the application of O'Brien TrueTube FS, TrueTube EP and TrueTube EPS where it is believed they offer the greatest customer value as sample transport tube in Tracepak® and Stackpak™ tubing bundles as well as bare tubing in sample conditioning systems. The recommendations below are based on reducing the effects of adsorption and desorption by the sample transport tubing.

Comparison of commercial tubing to the family of 316L TrueTube products:

Commercial Tubing	• 80 – 120 Ra • Contaminated with drawing oils and inclusions • High polar surfaces
Commercial Fused Silica Coated Tubing	• Fused silica coating applied to commercial tubing.
TrueTube FS	• Low Surface roughness < 40 Ra • Chemically polished and passivated prior to coating • Fused silica coating with enhanced bonding
TrueTube EP	• < 25 Ra Surface Roughness • Electropolished and chemically passivated • Enhanced Cr:Fe ratios for improved corrosion resistance
TrueTube EPS	• Electropolished tube as base material (TrueTube EP) • CVD applied amorphous silicon coating • Deactivation enhanced inertness and durability

Investigation

We investigated two characteristics of the tube surface: chemistry and profile or roughness. We found evidence that the effects of surface profile were more pronounced for H_2O than for the more reactive CH_3SH and H_2S samples tested. Conversely we found that surface chemistry had a greater relative impact for CH_3SH and H_2S samples. Clearly both surface profile and chemistry are important in every case. Separating the effects of either characteristic, surface profile and chemistry, are only of interest because of the difference in cost to control or alter them.

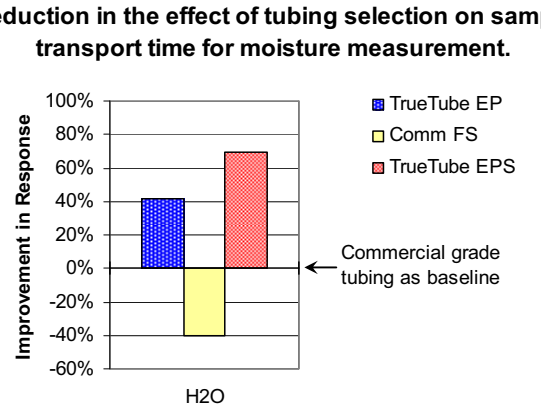


Figure 1 – Commercial grade tubing as baseline for moisture measurement.

The chart in Figure 1 illustrates the improvement in response time for different TrueTube variants. This chart illustrates the results from *"Relative Response Time of TrueTube when Measuring Moisture Content in a Sample Stream."*

For H_2O measurements the application of fused silica coated commercial tubing actually increased the response time. We believe this was due to the change in surface conditions resulting from the application of the fused silica coating where the coating has created additional sites where moisture may be trapped.

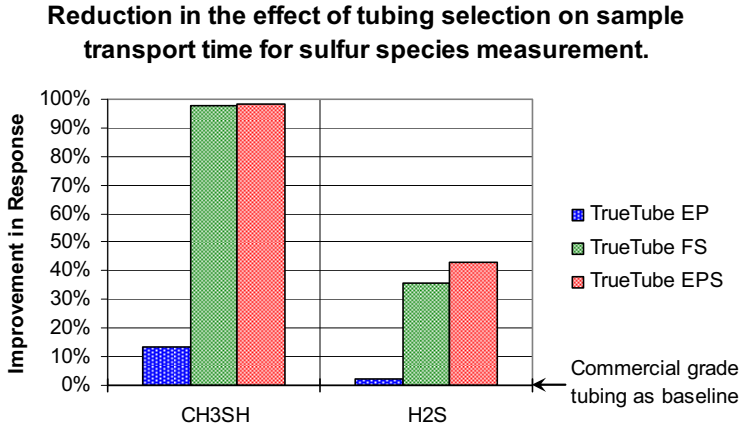


Figure 2 – Commercial grade tubing as baseline for sulfur species measurement.

The chart in Figure 2 illustrates the improvement in response time for different TrueTube variants. This chart illustrates the results from *"Testing Electropolished and Electropolished Silica Steel Coated Tubing on Adsorption of Methymercaptane"*.

The adsorption / desorption tests conducted with methylmercaptane (CH_3SH) show an improvement in system response by applying all of the TrueTube products. Similarly pronounced improvement was noted with both TrueTube FS and TrueTube EPS.

Testing conducted with a H_2S sample show that TrueTube EP had little or no long term effect on the adsorption / desorption of the sample when compared to the baseline. Only TrueTube FS and TrueTube EPS reduced the adsorption / desorption of the sample. While TrueTube EPS recorded initial improvements just 10% better than TrueTube FS we believe that because of its superior corrosion resistance it is the tube of choice for H_2S.

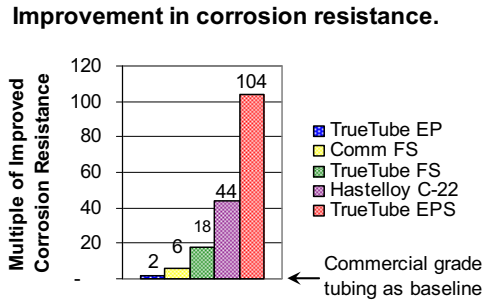


Figure 3 – Commercial grade tubing as baseline.

The chart in Figure 3 summarizes the results from *"Study of 6N HCl Corrosion on Commercial 316 SS, Hastelloy C-22 and TrueTube Variants."*

These corrosion studies provide the basis for our assertions that TrueTube FS is superior to commercial fused silica and that TrueTube EPS provides benefits well beyond any other choice including exotic alloys.

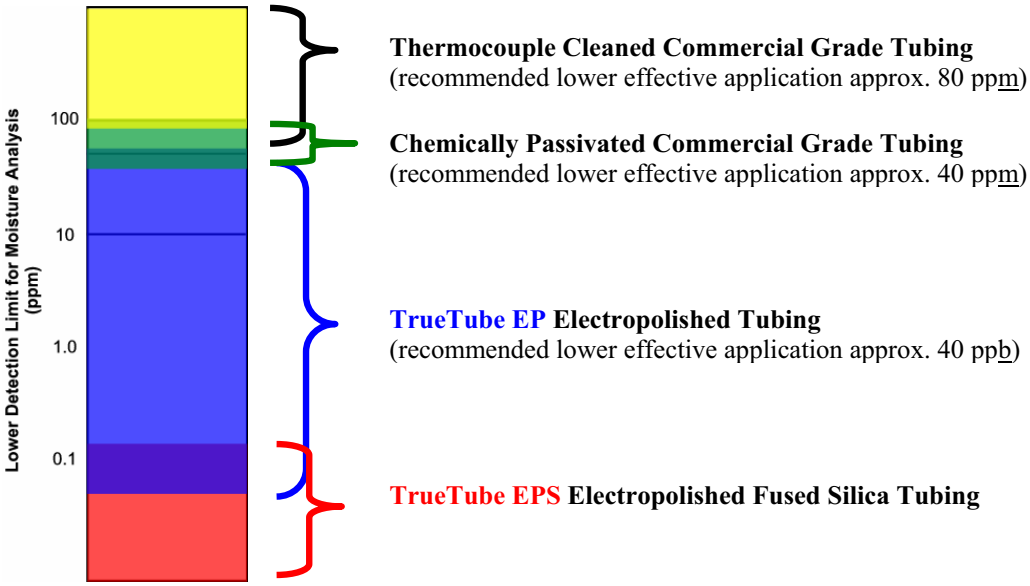
In explaining our assumptions we often turn to a familiar analogy of painting. Time and effort spent to prepare a surface prior to painting usually is not evident as soon as the paint is applied. It is not until some time later when the advantage of the properly prepared and primed surface show benefits; when it still looks as good as the day it was painted and the unprimed surface is flaking and peeling. We have every reason to believe that similar results will be found between silica coatings on commercial tubing and the silica coated TrueTube FS and TrueTube EPS products.

Compared to commercial grade fused silica TrueTube FS promises not only a longer product life but consistent performance. We begin with a low Ra tube and aggressively prepare the surface for coating by removing all contaminants and free iron. The result is a more consistent and denser coating on the surface of the tube. While this improvement may not appear to be substantial in the adsorption / desorption tests conducted it is our sincere belief that over time the TrueTube FS will outperform current commercial fused silica coated tubes.

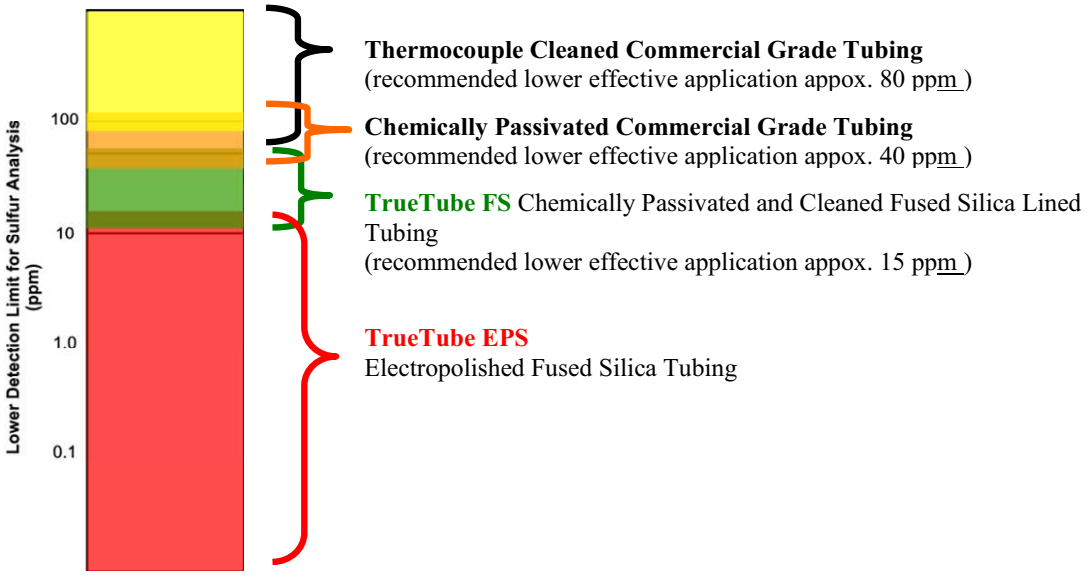
There is no mistaking the advantage of TrueTube EPS. The testing clearly indicates that TrueTube EPS has greatly improved corrosion resistance when compared to other methods or coatings. TrueTube EPS even outperformed Hastelloy C-22. The key to its corrosion resistance is that by starting with the electropolished base O'Brien provides an ideal substrate for the upgraded fused silica coating. In every test there was a noticeable reduction in the adsorption / desorption times with TrueTube EPS.

Recommended Considerations by Application

Moisture



Sulfur



Cost

This discussion would not be complete without addressing the differences in cost. Few of us can make decisions to use the 'best' option available with no regard to its cost. As in most things the higher performing options carry a greater cost. A one hundred foot long sample line bundle with TrueTube EPS may cost a five to ten dollars more per foot than a similar bundle with commercial grade stainless steel. Consequently this would add between five hundred to one thousand dollars to the overall cost of the installation.

Calculating the improvement in response time and accuracy, the initial cost of TrueTube FS, TrueTube EP or TrueTube EPS is quickly offset. The referenced tests indicate response times can realistically be expected to improve anywhere from 35 minutes up to 1 hour and 40 minutes.

Consider only the improved response time available by reducing the effects of adsorption / desorption in the sample transport system, what is the value to your company or unit to know that product is out of specification that much sooner? More importantly what is the value if you know the process is back in specification, producing sellable product, after an upset that much sooner?

Unit	Production Value Loss per Hour
800,000 tpy Ethylene	$50,000 / hour
250,000 tpy LDPE	$36,000 / hour
250,000 tpy EBSM Styrene	$33,000 / hour
200,000 tpy Fiber Grade Glycol	$31,000 / hour
200,000 tpy Antifreeze Grade Glycol (out of spec fiber grade product)	$3,600 / hour

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