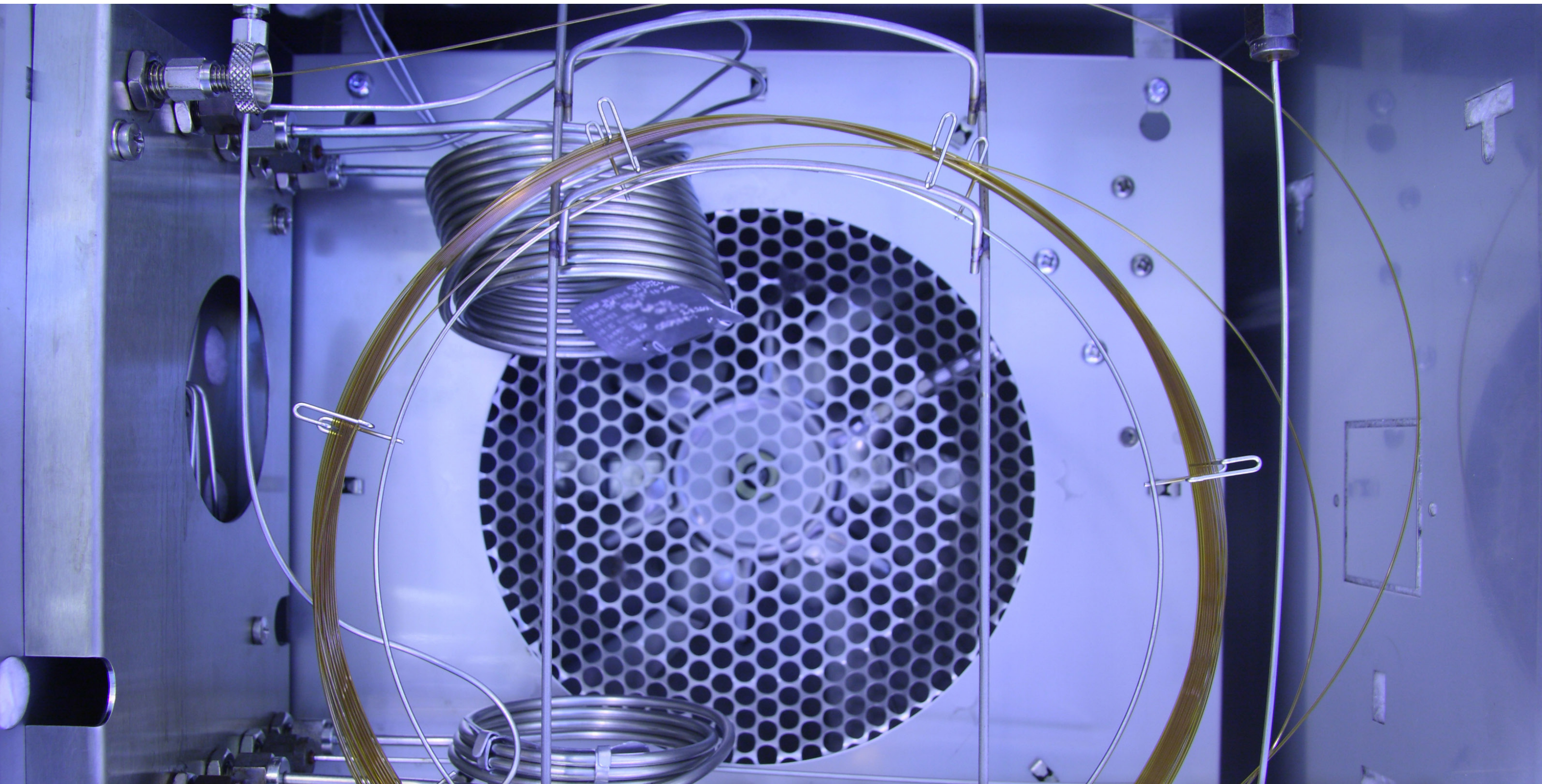
HandyTube
A STEEL PARTNERS COMPANY

WHITE PAPER



MANUFACTURING CONSIDERATIONS IN ULTRA-SMALL DIAMETER TUBING

When it comes to improving the performance of liquid chromatography and related microfluidics instrumentation, Ultra-Small Diameter (USD) capillary tubing plays a critical role. Industry leaders pushing the cutting-edge in chromatography require faster and more efficient equipment that can provide high-precision results. These key competitive advantages stem from USD tubing that can withstand high working pressures and that has an inside diameter that is both clean and smooth (low surface roughness). Achieving these properties presents unique challenges, as the outer diameter (OD) of the tube drops to USD sizes (less than 0.0625 inches). In this paper, we will explore what these challenges are, as well as the manufacturing solutions utilized by HandyTube to overcome them in order to manufacture high-quality USD tubing.

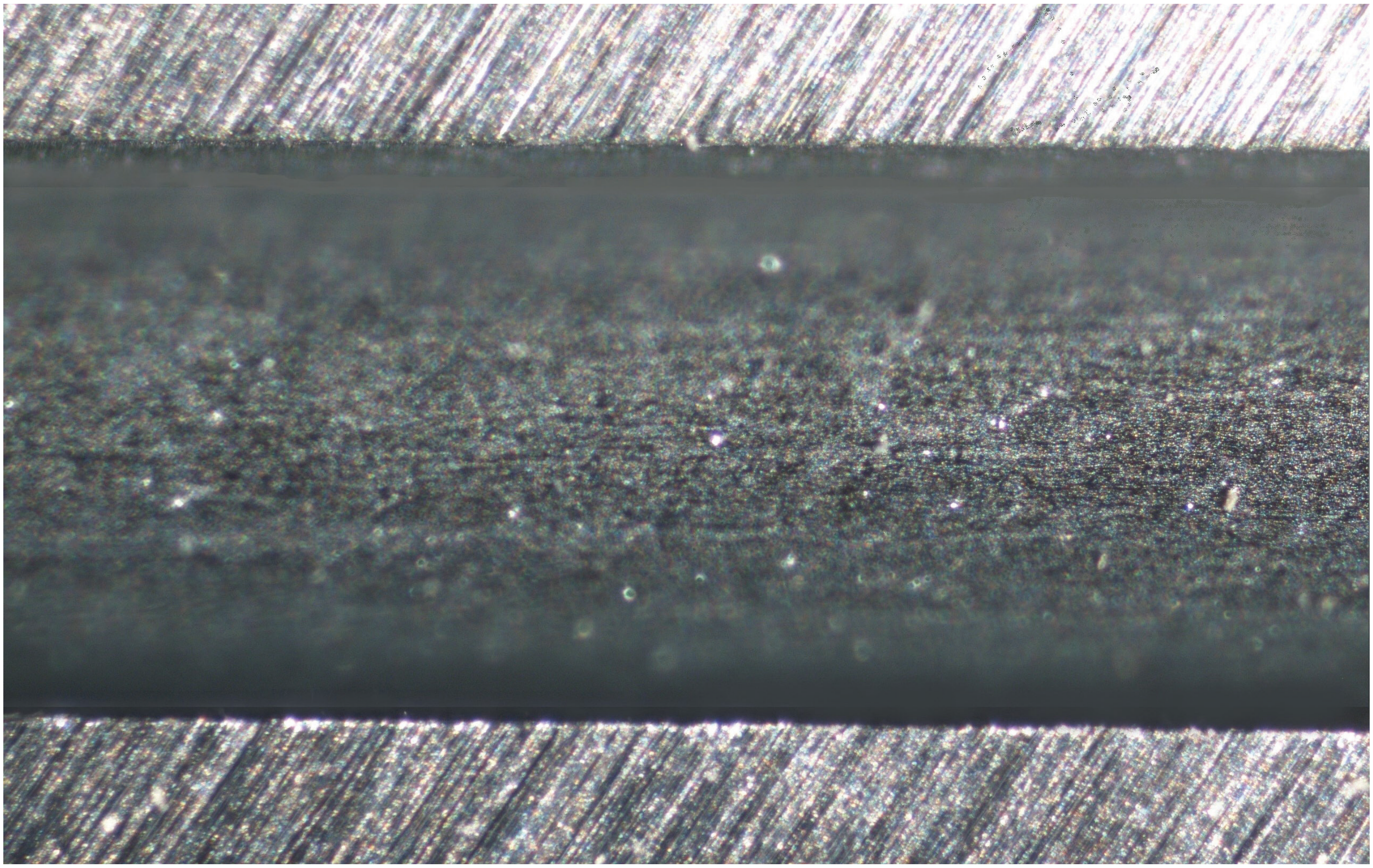
ID SURFACE ROUGHNESS

Ultra-small diameter tubing used in laboratory equipment, medical devices and other high-precision applications requires a smooth ID surface finish to ensure high-purity delivery of gas, solvents, chemicals and other media. Achieving proper ID smoothness is determined by two things: how the tube is first drawn, as well as the engineering expertise of the manufacturing supplier. Drawing, which reduces the tube's dimensions, is one of three main operations that occurs during the manufacturing process. The others are cleaning, to remove drawing lubricants, and heat treatment, to reset the mechanical properties and prepare the tube for redrawing.

There are two main types of drawing operations:

- **Floating plug.** Tubing is pulled through a conical die with a floating plug in the ID. Both the die and the plug determine the drawn OD and ID. This type of drawing involves more tooling and lubrication than other methods, but it yields tubing with more precise dimensions and a smoother surface finish.
- **Sink drawing.** Unlike floating plug drawing, sink drawing does not utilize an internal support. Tubing is pulled through a conical die, reducing the inside and outside diameters. The resulting ID is determined by several factors, including the inner and outer diameters of the stock tube, die angle and drawing stress.

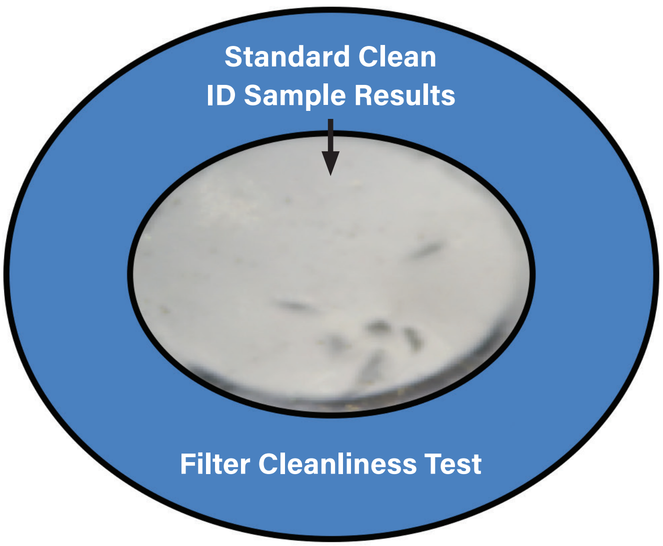
Answering the need for smaller tubing dimensions and smoother ID surfaces, HandyTube has developed proprietary tube drawing processes and equipment that can draw stainless steel in coil form, resulting in more reliable flow rates and faster sampling cycles in HPLC applications. Supporting the ID further along in the drawing process and holding tooling to more stringent requirements produces surface finishes as smooth as 20 Ra.

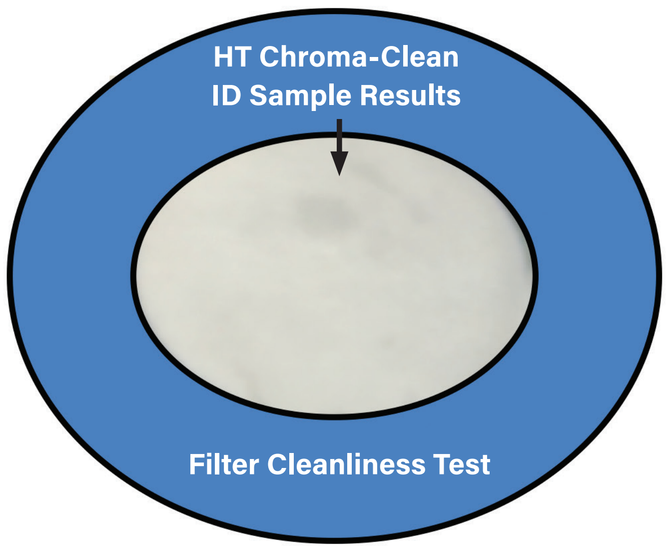


ID CLEANLINESS

Impurities in USD tubing, such as oil, grease, and other foreign material left over from the manufacturing process, can result in cross-contamination and inaccurate sample readings for the end user. To prevent this, conventional tubing requires additional cleaning prior to installation. For many end users, figuring out a way to effectively clean stainless-steel tubing in long lengths and with such small diameters poses a big challenge. Not only that, but as tube length increases and the ID decreases, the pressure needed to push any media through the coil tubing skyrockets. As a result, standard cleaning methods and equipment aren't effective in cleaning high-precision USD tubes.

HandyTube's proprietary cleaning methods can effectively degrease USD coil tubing several hundred feet long. After a tube is drawn, lubricant on the outer diameters is removed by HandyTube's degreasing process. The tube is then subjected to high pressures to remove ID lubricants. The specialized cleaning equipment allows HandyTube to process small-diameter tubing in long coils. HandyTube's ability to clean in coil form significantly reduces the amount of cleaning time required by OEMs and end users who would otherwise have to flush each straight length individually.



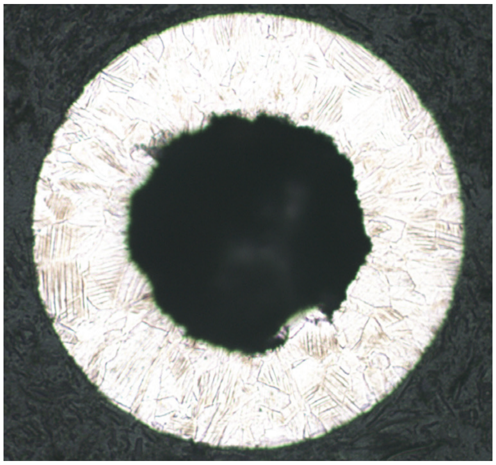


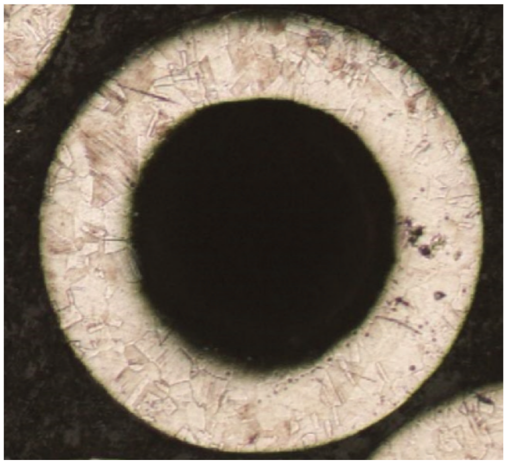
SEAMLESS ADVANTAGE

Welded tubing is made from a strip of metal that is rolled into a tube shape and longitudinally welded, while seamless tubing, as its name implies, contains no longitudinal weld seam; rather, tubing is extruded from a billet and drawn to finish. Many industries, including manufacturers of processing equipment and medical devices, require seamless small-diameter tubing, which typically has outer diameters between 0.018 and 0.0625 inches. Seamless tubes eliminate all the potential risks associated with weld seams, which include stress concentrators in high-pressure applications, inclusions, off-seam welds and contamination of the weld. As a result, industry standards rate seamless tubes at a higher working pressure than welded tubes of the same size. This high-pressure capability proves more and more essential over time as end users require smaller ID sizes, increasing the amount of pressure needed for media to flow.

MEASUREMENT QUALITY

When measuring the inside diameter (ID) size of USD tubing, the small dimensions make physical gaging problematic. The ID becomes more starburst-shaped as the tubing is drawn to smaller sizes. This unique geometry yields imprecise results when pinned with circular gauge pins to measure ID size. HandyTube uses a variety of proprietary measuring techniques to ensure that these geometric fluctuations are accounted for.





ALLOYS

When it comes to small-diameter tubing, the most common stainless-steel alloys are the 300 series, which is available in a variety of corrosion-resistant types and sizes. These alloys contain chromium, nickel, molybdenum and titanium, and are ideal for seamless coil-tubing applications. They can withstand high pressures and temperatures. Some specific types include:

- **Type 304/304L.** This non-magnetic, corrosion-resistant alloy is the most widely used of all the stainless steels. It has excellent weldability and forming characteristics and is resistant to moderately aggressive organic acids, including acetic acid and reducing acids.
- **Type 316/316L.** This alloy is more resistant to chemical attack and intergranular corrosion (IGC) than 304. This increased corrosion resistance is due to the addition of 2-3% molybdenum and is particularly effective in high chloride/saline environments.
- **Type 321.** Although this alloy is similar to 304 in terms of chemical composition, it contains titanium equal to at least six times the combined Carbon and Nitrogen content. The addition of titanium makes alloy 321 ideal for operating temperatures greater than 800°F.
- **Type 347.** This alloy offers higher corrosion resistance than type 321 in strongly oxidizing environments due to the additions of columbium and tantalum. 347 maintains this enhanced corrosion resistance even when exposed to environments between 800°F (427°C) and 1,650°F (899°C).