Vortab® Flow Conditioners Technical Note

Transitional Flow Effects on Flow Meter Measuring Accuracy

Vortab Flow Conditioning Eliminates Transitional Flow Effects

Vortab flow conditioners are widely recognized and applied in flow metering applications to correct the unpredictable effects of flow profile shifts caused by limited straight-run, upstream pipe geometry changes (e.g. damper positioning) and load changes. These unpredictable flow profile variations are neutralized as they pass through the Vortab flow conditioner to present a consistent, predictable outlet flow profile to the flow meter that results in accurate and repeatable flow measurements. Additionally, Vortab flow conditioners also efficiently neutralize transitional flow effects.

To appreciate the value of Vortab flow conditioning in applications with naturally occurring flow profile variations, it is first necessary to understand how flow profiles can change. Engineers specifying flow metering technologies are very aware that flow profile variations and unpredictability will directly result in measurement inaccuracy. Engineers further understand that flow profiles are a function of pipe geometry, Reynolds number (Re), internal pipe roughness and rate of change.

It is widely known that many diameters of uninterrupted straight pipe runs are necessary to produce the fully developed turbulent flow profiles preferred by many measuring technologies. However, in applications with low flow detection and wide turndown what is often overlooked is that the flow profile also "transitions" dramatically and without correction can result in tremendous flow metering inaccuracies over a portion of a critical measuring range. Consider the difference between laminar and turbulent flow conditions. Laminar flow occurs at low velocities where the Re number is below 2000. Turbulent flow typically occurs above Re of 4000. When flow occurs between the 2000-4000 Re region it is commonly referred to as being in the "transitional" flow range. However, depending on the direction, either increasing or decreasing flow, and the rate of change, transitional flow can continue up to 7000 Re.

As the Reynolds number and velocity increase from 2000 Re up to 4000 Re, the relationship between the average velocity V(avg) and the centerline velocity V(max) dramatically increases from 50% up to nearly 80%. Accordingly, the velocity profile from the centerline to the pipe wall is also changing at a dramatic rate. Insertion type, point flow measuring instruments will be susceptible to profile changes during this transitional flow range to large varying degrees. Virtually all point insertion type flow sensors are susceptible, regardless of whether they are centerline positioned or have variable insertion depths. These types of profile effects are generally more acute in smaller line sizes.

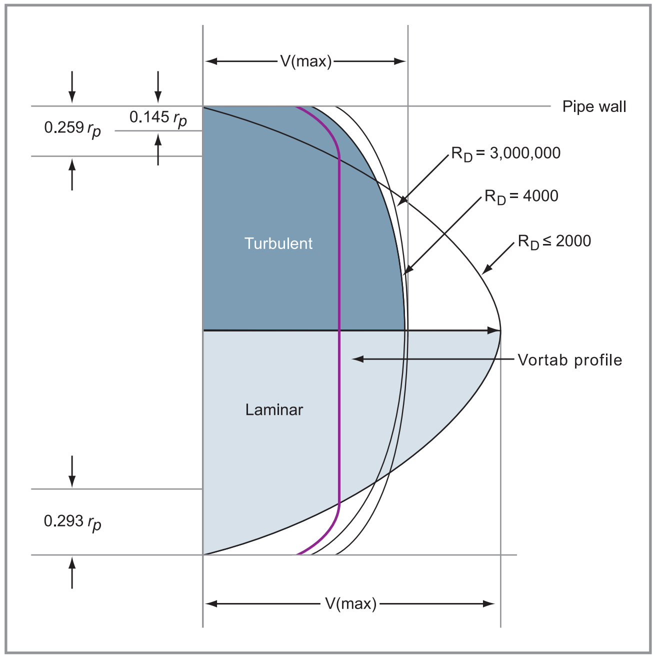

Figure 1. Laminar vs. turbulent flow profiles

The laminar profile takes on a parabolic shape where the relationship between the average velocity and centerline velocity is quite dramatic when compared to the turbulent flow profile.

Source: Richard Miller, *Flow Measurement Engineering Handbook*; Vortab profile added by FCI

Relationship: Average V (avg) and Maximum V (max)

In Figure 2, the centerline relationship between V (max) and V (avg) can transition from 50% to in excess of 80% as flow rates change from laminar to turbulent.

Vortab flow conditioners eliminate the unpredictability and unwanted effects as transitional flow profiles transition by producing a flattened, highly repeatable flow profile that remains essentially unaltered while velocities and associated Re numbers move from laminar through transitional to turbulent flow.

With a Vortab flow conditioner the relationship between V (avg) and V (max) is maintained and a nearly constant flow profile is maintained downstream. When a Fluid Components International (FCI) flow meter is paired with a Vortab flow conditioner, a stable and consistent flow profile, independent of direction or rate of change, is produced upstream of the flow meter, resulting in highly accurate and repeatable meter performance. In all wide turndown applications, FCI can easily determine whether transitional flows will occur within a specified metering range. However, it is more difficult to predict whether transitional flow effects will be broad or narrow, or specifically where they will occur over a critical portion of the desired metering range. Figure 3 shows an uncorrected flow profile effect and a Vortab corrected flow profile.

FCI's thermal dispersion type devices feature wide turndown capability and low flow sensitivity. As a result, it is very common for engineers to specify large turndown requirements that include laminar, transitional and turbulent profiles. Fortunately, it is relatively easy for FCI to calibrate for both laminar flow rates and turbulent flow rates during the same instrument calibration — these profile variations can be reproduced during laboratory calibration. However, whenever there are both laminar and turbulent profiles, there is always a transitional flow profile that contains tremendous variations. FCI flow meters are centerline mounted to consistently utilize the relationship between maximum velocity V (max), and average velocity V (avg) as centerline flows are the most predictable. When FCI flow meters are installed with Vortab flow conditioners, transitional errors are eliminated, which provides optimum accuracy through the entire metering range.

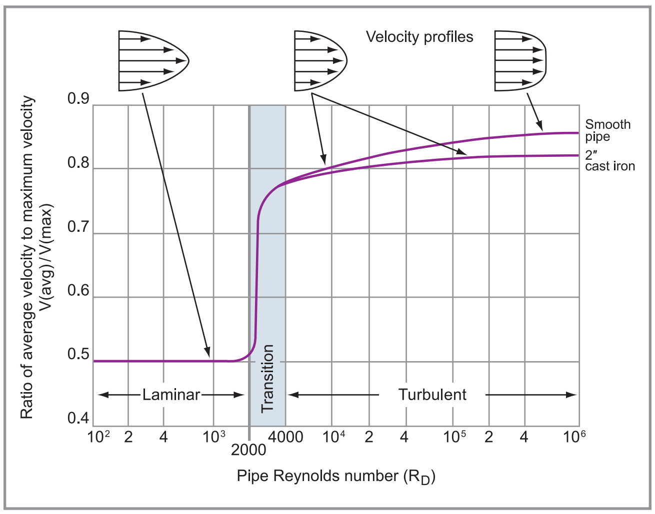

Figure 2. Ratio of average to maximum (centerline) velocity for smooth and rough pipe *Source:* Richard Miller, *Flow Measurement Engineering Handbook*

FCI Model ST75V (left, inset)

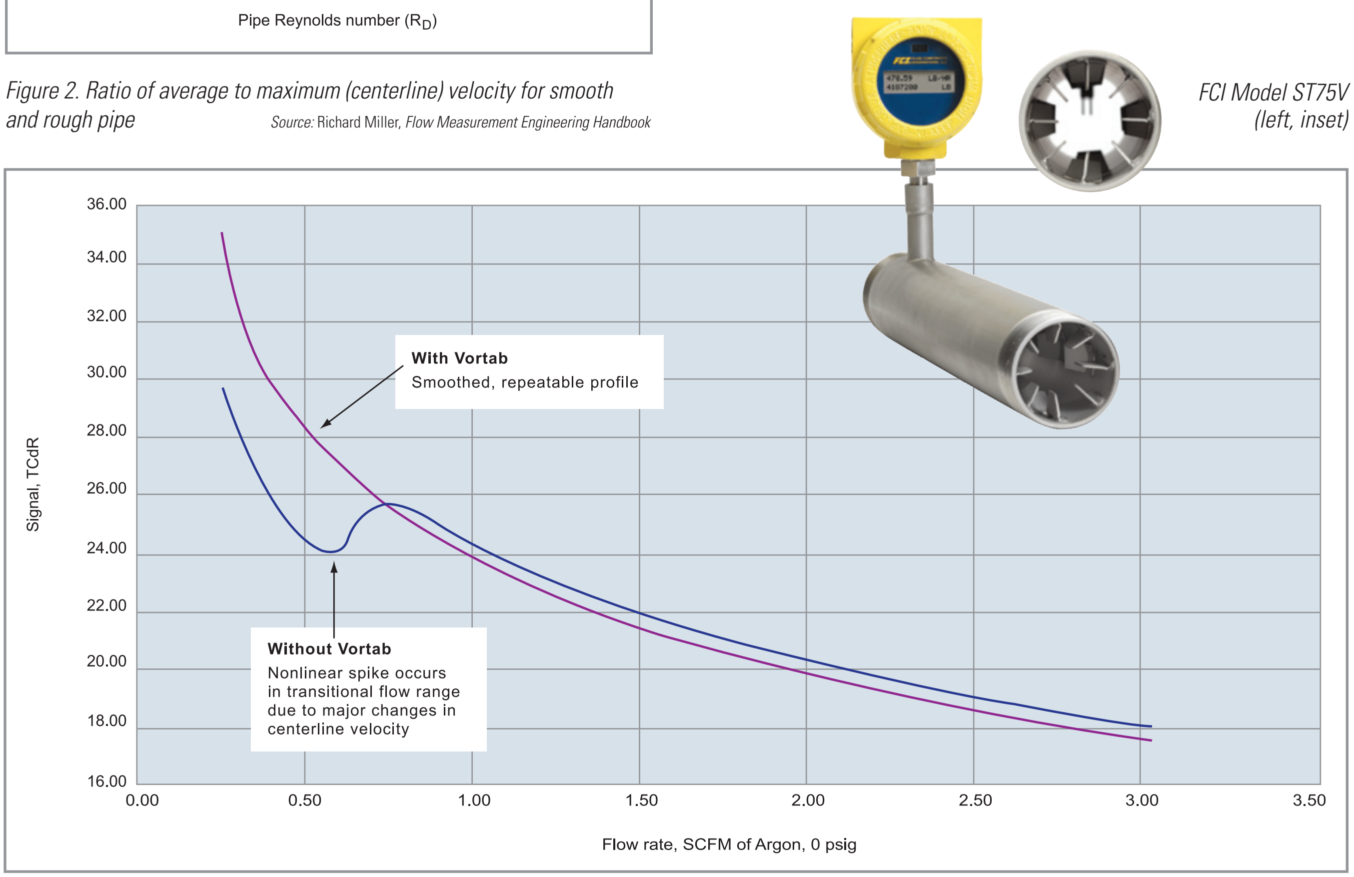

Figure 3. FCI ST Series Flow Meter in Argon

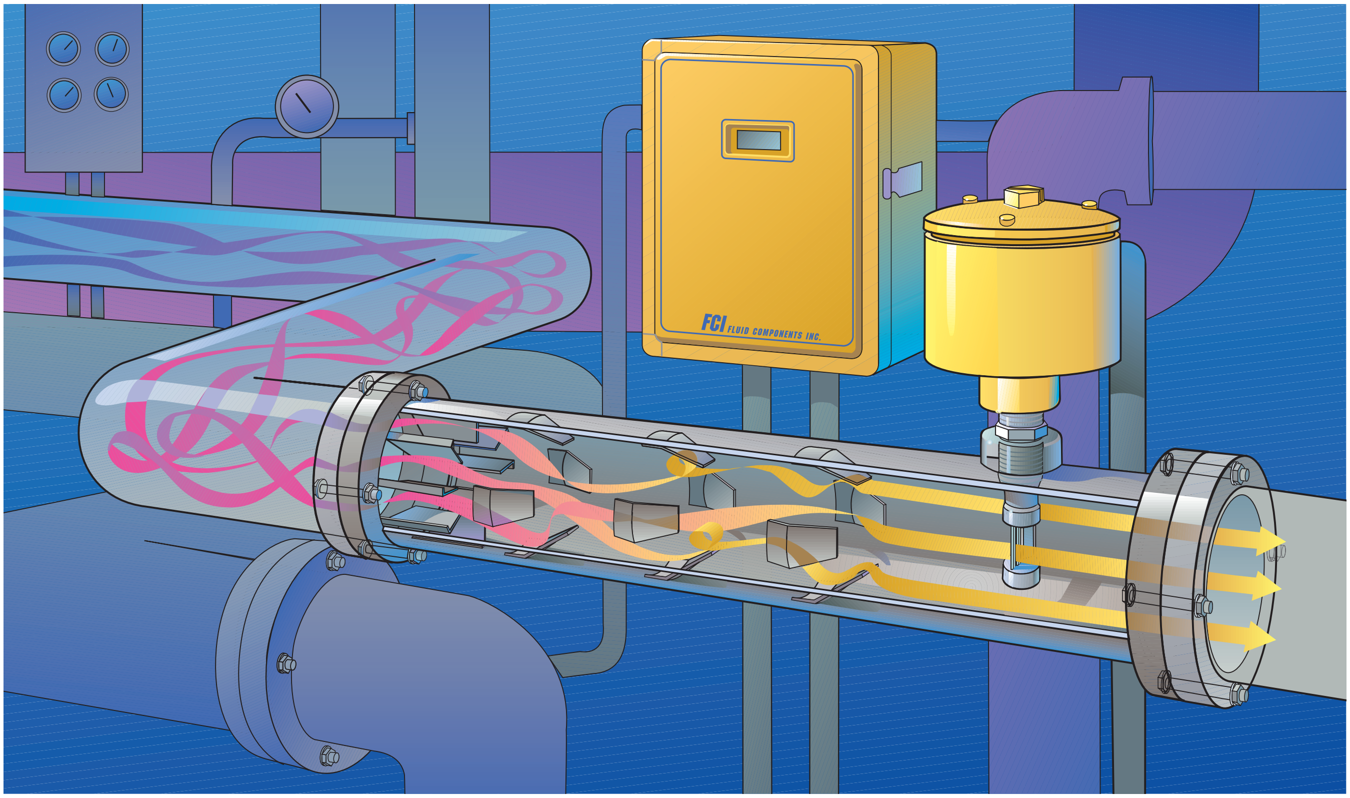

Figure 4. Vortab installation

Vortab Offers Double Duty Flow Conditioning

Vortab flow conditioners perform double duty by simultaneously isolating the flow meter from common distortions found in everyday process piping and eliminating the effects of unstable transitional flow profile variations. The net result assures continuous high accuracy and repeatable performance across the most extreme flow ranges, most importantly when critical low flow metering accuracy is at a premium.

Illustrated in Figure 4 is a typical Vortab installation with an FCI flow meter optimally located downstream of the Vortab exit. With the Vortab flow conditioner, the flow profile is essentially flattened. Most importantly, whether the inlet profile is a function of Re number, or whether it is distorted by upstream piping obstructions like elbows, valves and other pipe straight-run variations, the outlet profile remains unaffected. Over time, pipe roughness has a tendency to change as build-up or wear occurs. While pipe wall changes are subtle when compared to the change in flow profiles between laminar and turbulent flow, they are additional unwanted process phenomena that is mitigated with Vortab.

FCI AVAL Application Evaluation Software Delivers Confidence

To ensure accurate flow metering performance across the entire flow range, process operators must rely on flow meter manufacturers to provide clear notification when user-specified measuring ranges cross over flow profile variations. FCI AVAL application evaluation software provides accurate flow profile insights and always results in FCI offering the best flow metering solution. AVAL considers all process metering conditions and installation imperfections, including those virtually hidden to operators such as transitional flow profiles. AVAL will model installation conditions, including building detailed diagrams, and simulate over 30 common installation and flow profile variants caused by common piping practices.

Process operators and engineers can rely on FCI to provide process insights and solutions that will optimize total flow metering performance and ensure the best process operation and control. ■

FCI is ISO 9001:2000 and AS9100 Certified **Visit Vortab and FCI on the Worldwide Web:** www.vortab.com | www.fluidcomponents.com
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