Achieving Custody Transfer Accuracy

Using an Ultrasonic Flowmeter With Five Diameters of Upstream Straight Run

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Abstract

Hydrocarbon liquids, such as crude oils and refined products, have both high economic value and a hazardous nature. An accurate and repeatable measurement system is vital for both custody transfer and leak detection monitoring applications. Historically, the use of ultrasonic flowmeters has been hampered by the need for long, straight runs of pipe mainly upstream of the flow measurement point. This paper provides a description of the testing performed using our latest meter suitable for custody transfer applications, along with a look at the diagnostic capabilities of the flowmeter. Several meter configurations, including a single-plane four-path and double-plane eight-path flowmeters in sizes of 6 and 10 inches, we tested, and the results are presented here. By performing numerical studies across a wide range of Reynolds numbers, and through actual flow testing using several different viscosity oils, we were able to demonstrate the superiority of an eight-path meter when the only available option is a shortened straight run between meter and upstream disturbances. At higher Reynolds numbers, a flowmeter such as the Sentinel LCT8 meter (dual-plane, eight-path) shows a marked advantage over single-plane, four-path meters in conditions typically encountered in real-life situations. At lower Reynolds numbers, however, other fluid effects can adversely affect meter performance. Because the orthogonal planes of the eight-path meter can determine the actual axial and transverse profiles, the use of this type of flowmeter can further aid in diagnosing potential pipeline problems.

Sentinel LCT8

Introduction

"Custody transfer" in the oil and gas industry refers to the transfer of hydrocarbons from one owner to another. Given the economic value and hazardous nature of these assets, the industry requires high accuracy and confidence in the measurement system used. The flowmeter performance requirements are often governed by industry standards set by OIML (the International Organization of Legal Metrology) or API (the American Petroleum Institute), or by national regulations (such as INMETRO in Brazil), and through contracts between the two parties. Ultrasonic custody transfer flowmeters are often used in pipeline leak detection applications as well due to their ability to maintain accuracy through viscosity changes and maintain overall leak detection system uncertainty below ±1%.

In the past 10 years, ultrasonic flowmeters have seen one of the largest market share growths for custody transfer and leak detection metering. This growth has been largely driven by the advanced diagnostics capability of the meters, which can be used to identify when potential issues surface, infer other measurement parameters, and feed the AI (artificial intelligence) algorithms for the industry internet. Ultrasonic flowmeters tend to have higher capital expense costs compared to other technologies, but lower operational expenses because they often do not need to be recalibrated or re-proved when fluid properties change, such as at the start of unloading a new oil batch.

One historical weakness of the use of ultrasonic flowmeters for custody transfer has been the need for long straight runs. Typically, uninterrupted pipe run requirements have been twenty diameters upstream of and five diameters downstream of the meter itself. In some situations, the straight run could be reduced to ten diameters with the use of a flow conditioner. The associated pressure drop of a flow conditioner may be undesirable considering that one of the benefits of ultrasonic flowmeters is a low inherent pressure drop. Long straight runs have been typically necessary to ensure a fully developed flow profile with as little swirl as possible, which allows for a more accurate measurement of the fluid velocity at each acoustic chord location within a meter. With such well-conditioned flow, a four-path ultrasonic meter provides enough flow field velocity resolution to appropriately measure the flow meeting custody transfer accuracy expectations and holding performance through viscosity changes (within the calibrated Reynolds number range).

In some applications, especially skid-mounted meters for pipeline pumping stations or offshore platforms, the skid footprint is limited and may not have sufficient space for long, straight runs. In such cases, an eight-path ultrasonic flowmeter, such as the Panametrics Sentinel LCT8, can offer custody transfer accuracy with only five diameters of straight run between the meter and any upstream disturbances and may be the only available option.

Less sensitve to swirl

Eight-path meters, with orthogonal planes—where a pair of perpendicular, crisscrossing paths are both at the same radial distance from the pipe centerline—are less sensitive to the potential errors that flow swirl can cause because the transducer paths are symmetrical about the axial center line of the pipe, both from top to bottom and from one side of the pipe to the other. When the paths are cross-oriented this way, velocity swirl components generated by certain upstream disturbances, such as pipe elbows, are automatically cancelled out of the flow-rate calculations.

Figure 1 shows results from a numerical analysis, which were combined with test observations from early prototypes. More optimal chord locations were realized that could better handle both swirl flow and allow the meter to perform over a wider range of Reynolds numbers (Re), covering a much broader range of fluid viscosities.

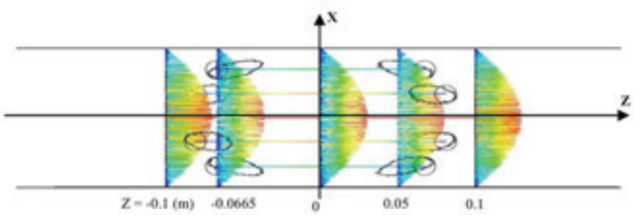

Figure 1. Computational Numerical Simulations Including Transducer Port Effects

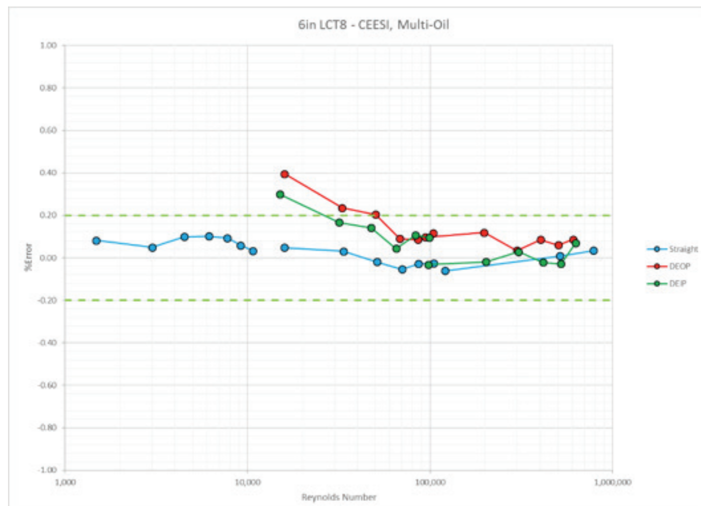

Figure 2. Performance Results of a 6-inch Sentinel LCT8

Corrections and adjustments not needed

Figure 2 is the performance plot of a 6-inch Sentinel LCT8 initially calibrated and verified in a long, straight-pipe setup, and subsequently installed only five diameters downstream of a double elbow in plane pipe configuration (DEIP), and five diameters downstream of a double elbow out of plane (DEOP) pipe configuration. Figure 3 shows similar results for a 10-inch Sentinel LCT8, including a test of the meter five diameters downstream from a fully opened globe valve (more disruptive to flow than a full port ball valve). The testing was carried out across a wide range of Reynolds numbers using several oils of different viscosities. For both meters, the correction factor tables were derived strictly from the straight-pipe configurations. No additional corrections or adjustments were applied to either meter during the subsequent cases of disturbed pipe flow to achieve the plotted accuracy.

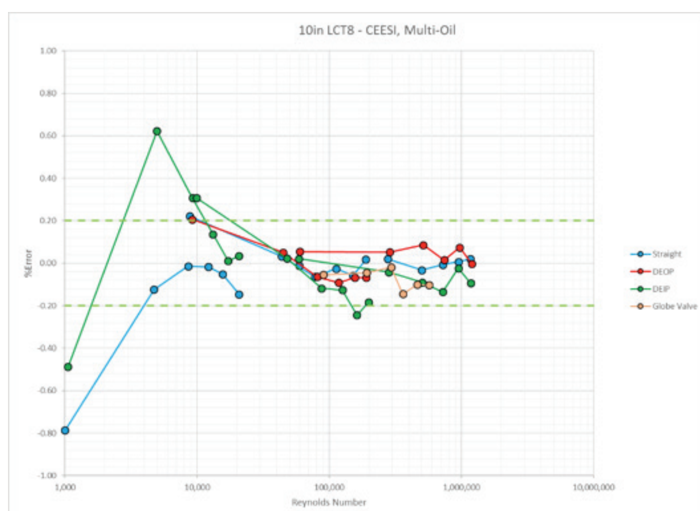

Figure 3. Performance Results of a 10-inch Sentinel LCT8

The results show the insensitivity of the Sentinel LCT8 to the standard upstream disturbances that are typically encountered in actual installations. While the performance of the meter tails off at lower Reynolds numbers, the benefits of an eight-path meter are most notable above Re of 10,000. While maybe not the tightest accuracy, the meter still shows good performance below Re of 10,000. At these lower Reynolds numbers, other fluid effects, such as transition flow, begin to dominate the flow behavior, which can adversely affect meter performance.

More accurate composite volumetric flow rate

One of the benefits of the cross-paths of the Sentinel LCT8 meter is the ability of the meter to use the velocity information from the two individual transducer planes, A and B, to resolve the true flow profiles both in the axial (down the pipe) and transverse (swirl and cross-pipe) directions. The individual plane velocity profiles of Figure 4 are manipulated mathematically into the bulk axial and transverse flow profiles of Figure 5. The plots are from the 6-inch DEOP configuration data of Figure 2. The pipe flow rate is calculated based on this real resolution of the axial flow velocity, rather than being calculated based on an erroneous single-plane "axial" profile that is influenced by the swirl component of the flow. Using the resolved axial flow velocity in this manner yields a composite volumetric flow rate that is more accurate. With a correction factor based on straight-pipe calibration applied to the composite volumetric flow rate, the most accurate flow rate can be calculated for the given properties of the fluid.

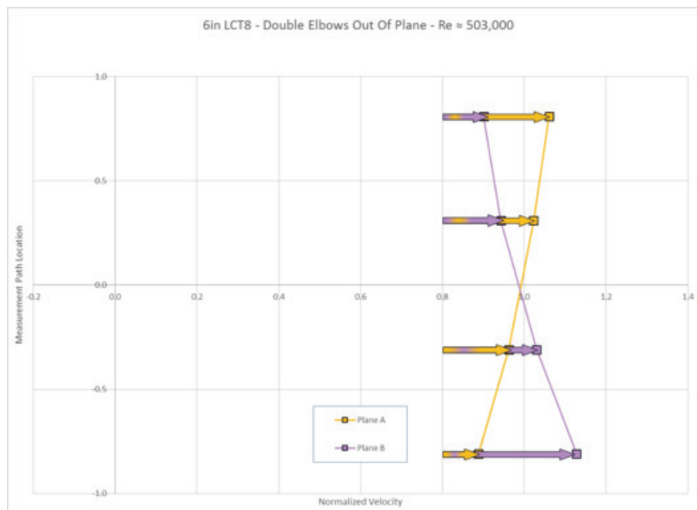

Figure 4. Velocity Profiles Measured by Individual A and B Planes

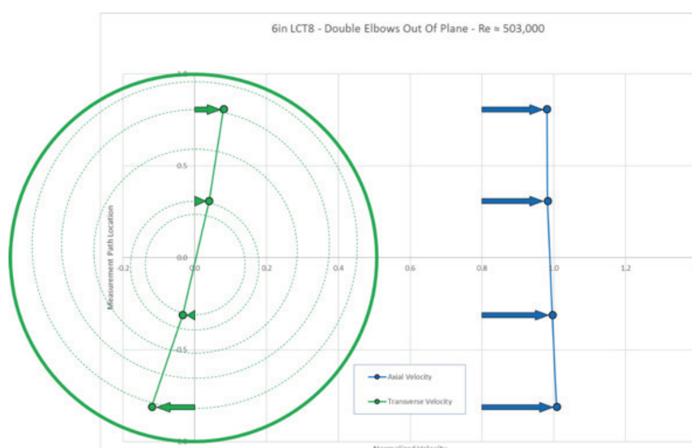

Figure 5. Axial and Transverse Velocity Profiles as Resolved From LCT8 Cross-Planes

Two planes improve performance

Figure 2 shows that an eight-path meter can perform well only five diameters downstream of a DEOP disturbance, at least above an Re of 10,000, though the performance does degrade as the Reynolds number decreases. Also of interest is investigating how a single-plane, four-path meter would handle the same disturbance. Are eight paths necessary or can a less-complex four-path meter do the job? Figure 6 breaks down the composite performance of the eight paths, as well as the performance of each four-path plane taken on its own for the 6-inch Sentinel LCT8 downstream of the DEOPs.

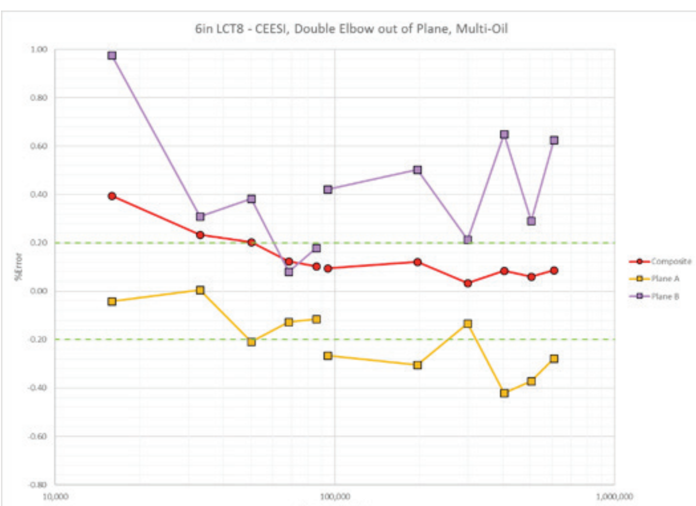

Figure 6. Performance Comparison of the 6-inch LCT8 Against Separated Four-Path Planes

Figure 7 is the similar test regiment data plotted as in Figure 6, but for the 10-inch Sentinel LCT8 meter, also downstream of the DEOPs.

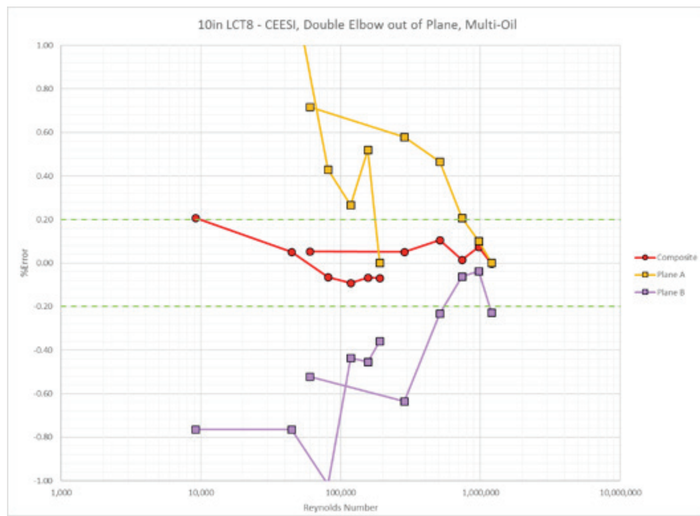

Figure 7. Performance Comparison of the 10-inch LCT8 Against Separated Four-Path Planes

Immediately evident in both Figures 6 and 7 is that a single-plane four-path meter, taken on its own, performs much worse than when the velocities of all eight paths of the two planes are taken together. The improved performance of the two planes is a direct result of the cancelling out the asymmetry of axial flow profile.

Conclusion

In conclusion, the Panametrics Sentinel LCT8 Ultrasonic Flowmeter shows good insensitivity to common upstream flow disturbances. The performance data presented was gathered from actual flow testing of two typical meter sizes: 6 inches and 10 inches. The performance improvement of a dual-plane, eight-path meter over a single-plane, four-path meter in the same disturbed flow condition is apparent when comparing the calculated composite flow rate of either meter against the test reference meter. A secondary benefit of meters that utilize orthogonal paths, such as the Sentinel LCT8, is the ability of the meter to resolve the velocity profile into the axial and transverse profiles. Such diagnostics can be used to identify pipeline problems that may develop over time.

About the author

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Nick has been working with the Panametrics ultrasonic flowmeter brand for fifteen years, specializing in meter flow performance testing, calibration, metrology, and certification.

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