



## Shippers, Bunker Suppliers Eye Coriolis Meters

By David Murray

After years of discussion and testing among oil companies, marine standards organizations, and shippers, the marine bunkering world seems to be on the threshold of a metering revolution that promises to end disputes over fuel loading amounts, and also to replace conventional paperwork with automatically generated “irrefutable” data, thus speeding turnaround times and reducing costs for shippers worldwide.

That’s the promise of those promoting the adoption, as a standard of bunkering and fuel-transfer, of automated bunkering systems incorporating Coriolis mass flow meters. Coriolis flow meters have been a hot topic for the past several years in specialized publications like *Tanker Operator*, *Bunkerspot*, and *BunkerWorld*.

The meter’s promoters include some of the biggest names in oil and marine transportation, notably BP, Maersk—and Buffalo Marine Service, which has used Coriolis meters since 1993 and strongly champions the technology.

### Questions Answered

In October, an engineer for a company that makes rival flow meter solutions questioned the efficacy of the Coriolis meter. Tommy Christensen, a project and business development manager for CBI Engineering A/S, told *Bunkerworld* magazine, “Coriolis mass flow meters measure liquid but do not necessarily differentiate between liquids. What if a supplier adds water, or any other low cost liquid—is the Coriolis flow meter able to detect this? I think this is a question nobody really wants to answer.”

But one person did—Buffalo Marine’s Tom Marian, who posted a lengthy response to *Bunkerworld’s* site. He documented, as he has before in magazine articles, his company’s record of reliable service from Coriolis meters.

Buffalo Marine installed its first three Coriolis meters in 1993, aboard its custom blending barge, the Buffalo Star, the only one in operation. (The Coast Guard has since disallowed blending barges, but “grandfathered in” the Buffalo Star.) “Since that time,” said Marian, “there has not been a single shortage claim and the meter readings have always synched up with the tank gaugings.”

Even though the meters’ maker, Emerson Micro Motion, said they did not need calibration, “out of an abundance of caution, Buffalo Marine sent the meters back to the manufacturer in 2003 when the blending barge was undergoing its decennial overhaul and drydocking to comply with U.S. Coast Guard regulations and Buffalo

Marine's preventive maintenance program." Bench-testing found that "the meters were well within accuracy tolerances."

In December 2009, *Bunkerspot* magazine publicized a bunker loading incident in which both the loading vessel, Buffalo Marine's mv. San Joaquin, using a FuelTrax bunkering system and the receiving vessel, the mv. Maersk Wyoming, were equipped with identical Coriolis metering systems.

After seven hours of pumping, both vessels printed out fuel tickets that differed by only 0.05 percent. The ship was confident that they got the amount of fuel they paid for and went on their way.

### **From PD Meters To Coriolis?**

While there exist 13 types of meters for measuring flows of liquids or gases, the most common in the marine industry are positive displacement (PD) meters. They come in many designs, using rotating crescents or paddles, vanes, or oscillating pistons to measure fluids by repeatedly trapping and releasing samples. They measure volume rather than mass.

This "volumetric" method has been compared to filling and emptying buckets and counting the number of times the "bucket" has been filled. The seals of some PD meters can be damaged by abrasives or corrosives, and they can be expensive in sizes above 10 inches. Their accuracy can also be compromised by drops in pressure or what the bunkering industry calls air entrainment—trapped bubbles.

More important, positive displacement (PD) meters have to be regularly disassembled, cleaned, recalibrated and recertified. Coriolis meters, by contrast, since they have no moving parts, never need to be disassembled and cleaned, only flushed. Also, since PD meters measure volume, they are vulnerable to temperature changes that can affect volume by expanding or contracting liquids or gases.

Coriolis meters directly measure mass, density, and temperature, and use these to calculate accurate volume. Besides marine fuel applications, Coriolis meters are now widely used in the beverage industry, to measure pharmaceuticals, and to monitor greenhouse gases in flues of power plants.

In March 2009, according to *Bunkerspot*, technology made by Micro Motion was being used in 600,000 Coriolis meters around the world.

### **Measuring Coriolis Force**

The Coriolis effect—named for French scientist Gustave-Gaspard Coriolis, who first described it mathematically in an 1835 paper—refers to the deflection of moving objects in a rotating context (like the Earth's surface).

Contrary to popular belief, the Coriolis effect on flows in sinks and drains is too small to be visible to the naked eye; perennial stories about sink drains reversing their rotation as ships cross the Equator are myths.

But with sensitive enough sensors, Coriolis force can be measured in liquids flowing through a tube. The liquid's density is measured by vibrations traveling

through it at a known frequency from two different sources. Sensors measure and compare the overlapping sine waves generated. Measurement depends on oscillation.

There are two types of Coriolis meters. One is in the “classic” delta shape, in which two tubes split the flow into a delta, or triangle shape. The tubes are then energized to flex, which generates oscillations at a known frequency, like a tuning fork. Two sets of signal drivers and pickups, at the entrance and exit of the meter, generate and measure the oscillations. The delta shape has historically been the most accurate, is easier to make and more reliable. But as technology has improved, even straight-tube meters have gotten more accurate and are suitable in many applications. .

(Those interested in a more detailed explanation, with a useful Web animation, can view the Web tutorial provided by Emerson, a leading manufacturer of Coriolis meters through its Micro Motion division, at [www.emersonprocess.com/MicroMotion/tutor/tutorlearningobjectives.html](http://www.emersonprocess.com/MicroMotion/tutor/tutorlearningobjectives.html) .)

### **Fighting The “Cappuccino Effect”**

A big concern for the bunkering industry has been entrained air, or air bubbles that can create a froth some call the “cappuccino effect.” Because some bunker fuels are so thick, air bubbles can remain trapped for hours. Entrained air is encouraged by the practice of “tank stripping,” in which pumping from the bottom of a fuel tank can produce froth and bubbles.

The result is what fuel chemists call a two-phase flow (fuel and air). Some types of flow meters, including older versions of Coriolis meters, proved not to accurately measure such flows, leaving the way open for disputes over fuel loading, since the bubbles or foam show up as “noise” in measurements.

Of course, the cappuccino effect can also be deliberately induced to make a delivery appear to be a greater volume than it is. Since most vessel operators manually strap tanks to obtain a volume, then convert that to mass, dishonesty can be hard to detect immediately. This is a particular concern in some overseas ports. A ship takes on what appears to be 1000 metric tons of fuel, leaves port and then two days later when the bubbles are gone, realize that they have been shorted.

But apart from deliberate dishonesty, PD meters themselves can make “cappuccino”; that’s why they require air eliminators and fuel screens—which must also be cleaned and recertified, along with the meters themselves.

### **BP’s Study Aims To Set Standards**

In 2007, BP’s Marine Fuels division embarked on a series of studies designed to revolutionize and standardize new industry practices in handling bunker fuels. BP drew up a document stating its specifications for the ideal fuel-handling system, including metering. Its stated goal was to reduce fuel and bunker discrepancies by at least 2 percent, whether they were due to error or dishonesty.

Among the goals of this system were the replacement of human-generated paperwork by automated systems that monitored fuel transfer and generated all the data points needed. But for that to happen, measurement would have to be precise and “irrefutable,” so as to eliminate disputes about the exact amount of fuel transferred.

There can be differences in systems using Coriolis meters, reflecting different pumping and loading practices, according to Robert Blakeney, business development manager at Nautical Control Solutions, whose FuelTrax monitoring system uses Coriolis meters.

“They’re accurate when they’re sized and used properly. Where you have different results, what you get is that the meters are measuring work practices.”

### **Microprocessors Were Key**

The Foxboro Coriolis Meter made by British company Invensys was chosen by BP for initial tests of its bunker system. It met one of BP’s key tests, the ability to consistently distinguish fuel from bubbles within it. In 2008, Maersk conducted tests using a Micro Motion Elite CMFHC3 Coriolis meter on its Victrol Barge in Antwerp, Belgium, over a six-month period.

It appeared the “cappuccino effect” was overcome. But Coriolis meters had been around for more than 30 years. What had changed? Why did it take until 2007 for BP to begin its experiments? The reason may have to do with Yogi Berra’s saying: “In theory there’s no difference between theory and practice, but in practice, there is.”

In theory, the Coriolis meters worked reliably, but in practice, they needed to be paired with advanced microprocessors capable of very fast calculations to adjust in real time to changes in density and temperature. In 2009, Brian Dickson of Invensys said it was the addition of advanced microprocessors that made the difference. Previously, as little as 2 percent of entrained bubbles could skew measurements.

“Advanced digital Coriolis meters have changed all that,” said Dickson. “Microprocessors in their transmitters run advanced digital signal processing techniques that provide useful measurements of both mass flow and density, ensuring stable operation in either single-phase or two-phase flow conditions, such as those found in bunker fuel transfer.”

Invensys designed a frame housing or skid for the flow meter that’s half the size of a standard 20-foot container, with easy “plug-in” connection points. The Singapore Maritime Port Authority performed real-world tests with the system in 2007, along with the BP barge *Pride*.

### **Boom Market**

So is Christensen right?

In some instances, said Blakeney. “Coriolis meters are sensitive to sizing flow rates issues,” he said. “If improperly sized to fuel type and pumping flow rates, accuracy can indeed be affected.”

“However, when I order a Coriolis meter from Micro Motion,” said Blakeney, “I have to submit a form outlining fuel type, the operating temperatures, flow rates, and viscosity of the liquids being measured. Then Micro Motion can then supply the correct size of meter based on what they call these ‘process conditions’. They have years of experience and historical data to support this effort, and the meters do perform as expected. The FuelTrax systems we have installed using Coriolis meters have performed well and our customers are happy. ”

Flow Research, which publishes reports for the world’s flowmeter customers, said on October 26 that it expects 2009’s flowmeter sales of about \$4.6 billion to grow to more than \$5.5 billion by 2014.

The report adds, “Ultrasonic and Coriolis flowmeters for custody transfer measurement are two of the fastest growing segments.”