BY JOEL WEINSTEIN AND DAVID ASHLEY HAYES,
EMERSON PROCESS MANAGEMENT

Marine Fuel Management

Introduction

Marine fuel costs represent a major portion (60–70%) of a ship's operating cost. With increasing oil prices and conservation efforts, careful fuel management and increased engine efficiency have become vital for environmental and financial reasons. Fuel flow measurement with Coriolis technology provides the foundation for increased fuel efficiency and accurate accounting of fuel purchases. Even a medium-sized 30,000 DWT vessel can consume 20 tons of fuel oil per day, which at today's prices is greater than USD6,000 per day. This white paper describes how Micro Motion Coriolis meters can decrease the cost and waste associated with the fuel supply chain, from on-shore blending and barge loading to ship bunkering and fuel efficiency optimization.

Coriolis Measurement of Fuel Oil

The adoption of Coriolis flow meters is increasing in the marine industry because Coriolis meters offer solutions to many of the challenges faced in fuel metering applications. Coriolis meters are non-intrusive, meaning that there are no moving parts or obstructions in contact with the fluid being measured. Coriolis meters provide continuous on-line measurement of mass flow rate, volume flow rate, density, temperature, and batch totals—all from a single device. Coriolis meters have no complex moving parts and require no maintenance, and they require no flow conditioning or straight pipe runs. Unlike volume measurement, mass measurement is independent of operating pressure and temperature, which negates the need for error-prone density conversions. Coriolis meters also provide extremely accurate flow and density measurements.

For high-viscosity fluids, especially fluids with entrained gas, direct mass flow measurement is superior to competing technologies such as volumetric meters and tank gauges. Consider the measurement of bunker fuel with 5% entrained gas. A volumetric meter or a tank gauge will give liquid oil batch errors of +5% compared to true batch totals, even if the meters are functioning perfectly. The reason for this is that each meter simply measures the volume of what is going through it, i.e., a mixture of gas and bunker fuel. The operator sees this measurement as liquid volume flow. The low-density entrained gas takes up a lot of space (i.e., volume), which the operator misinterprets as a large volume of oil.

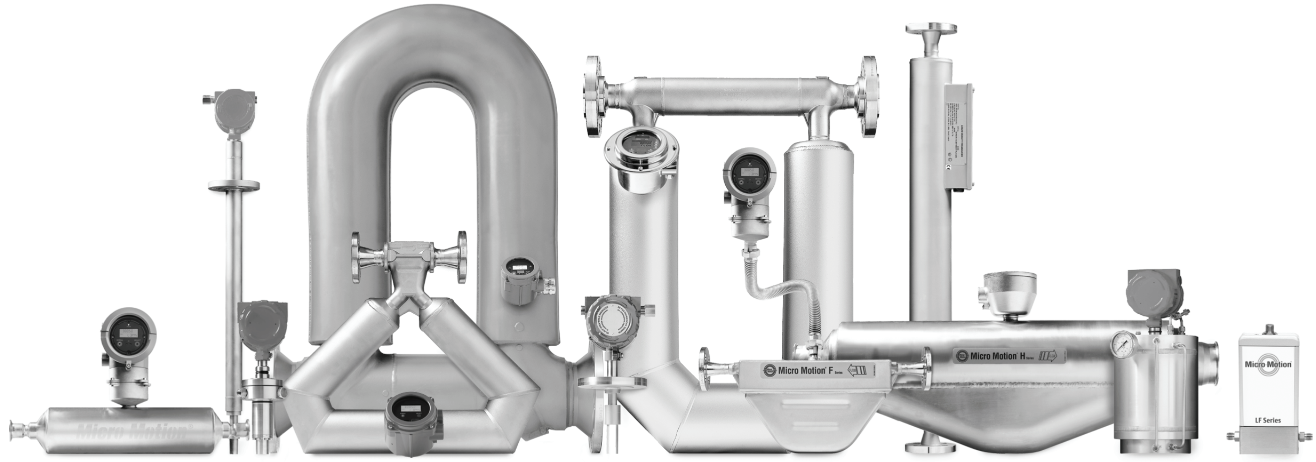

Figure 1. Micro Motion Coriolis Flow and Density Meters

The mass of the entrained gas, however, is so small that it does not contribute significantly to the total mass of the mixture. A Coriolis meter, which measures mass flow directly, will therefore measure precisely the quantity needed.

Marine Fuel Blending

Blending is defined as the combination of raw material in exact proportion to meet specific requirements. The typical blending operation requested by the marine industry involves the combination of heavy fuel oil (HFO) or Bunker C, and an intermediate fuel oil (IFO), which is available in a range of viscosities and sulphur contents. The International Standard Organization (ISO) has specifications for marine fuels supplied worldwide for use on board ships. There are nineteen categories of residual fuels available. Out of those nineteen, five categories or grades are most frequently supplied and used by ships: IFO180, IFO380, IFO500, MDO, and MGO.

Precision blending of these fuels at the supply hub is very important due to increases in fuel prices, engine wear from different fuel grade burn temperatures, and the limitations associated with shipboard storage. Pre-load blending guarantees that a vessel receives fuel with optimal properties for the intended use of specific on board engines, leading to reductions in NO_x and SO_x emissions. The pre-bunkering blending of fuels has also been increasingly popular in the marine industry due to regulations that discourage the mixing of fuels inside a particular tank on board. On-board mixing has been at the center of a growing number of bunker dispute claims, machinery failures, and failures to meet environmental standards.

Improved quality control of marine fuels by continuous blending measurements can address all of these concerns, as well as help improve fleet-wide fuel efficiency. Micro Motion Coriolis meters have been used for many years in a variety of blending applications, including hydrocarbons. Figure 2 shows a blending solution provided to a large fuel supplier using two Micro Motion Coriolis meters for the blending of HFO and diesel fuel. A control system uses the mass flow outputs of the two Coriolis meters to determine the exact set-points of the two downstream valves to control the desired fuel quality.

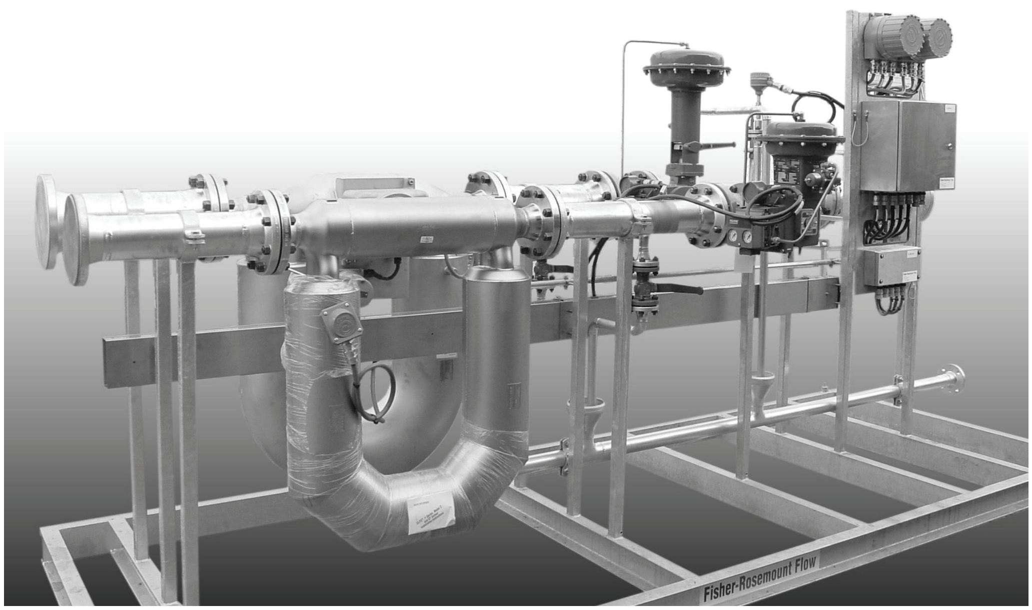

Figure 2. Marine Fuels Blending Solution

Marine Fuel Bunkering

Marine fuel measurement during bunkering provides better control over and visibility into the amount of fuel received by vessels, and is perhaps the most essential component of fleet-wide fuel management. Traditional fuel oil bunkering methods are based on volumetric tank measurements and a reference density (typically obtained by laboratory sample). Look-up tables, the reference density, and the "dip," are used to calculate the total mass of the bunker fuel delivered. Measurement accuracy depends on many factors including temperature, pressure, presence of entrained gas, dip tape, tank volume uncertainty, accuracy of conversion tables, human error, and how well the density sample represents the average batch density (HFO tends to stratify in tanks). These systems have typical mass total accuracies on the order of 1–3%, and in some cases as poor as 5%. Additional inaccuracies can occur due to dead volumes in tanks or aeration of oil, both of which increase the apparent volume of oil delivered.

Although some HFO suppliers have advanced laser level gauges, multiple sample points, and highly accurate look-up tables, a direct Coriolis mass measurement completely avoids the problems inherent in volumetric tank measurement. Coriolis meters deliver the mass total without all the instrumentation and measurement conversions. In addition, because the mass of air is negligible, ship owners do not pay for air that has intentionally or unintentionally found its way into the fuel. Coriolis mass flow technology is well-suited to HFO applications, particularly bunkering, where customer billing is based on mass.

However, metering HFO is not an easy application for flow measurement technologies, even those with direct mass capability. Flow meters must be able to handle the thick, viscous bunker grades used, along with any impurities that have not been filtered out, and varying amounts of entrained gas in the oil. This makes for a very challenging application, not to mention other environmental influences such as vibration, product solidification, and the need for low pressure drop. Several successful customer trials by Maersk, Exxon, Victrol, and others show that Micro Motion Coriolis meters can perform under harsh marine conditions.

Engine Fuel Measurement

A tiny increase in engine fuel efficiency can lead to dramatic fleet-wide savings. Accurate measurement and control of fuel oil supplied to marine engines allows operators to optimize engine use and save fuel wherever possible. While marine engines vary by vessel, an example of a 10-cylinder marine engine is shown in Figure 3. Meters can be mounted in the fuel supply and return lines of each cylinder to measure differential mass consumption.

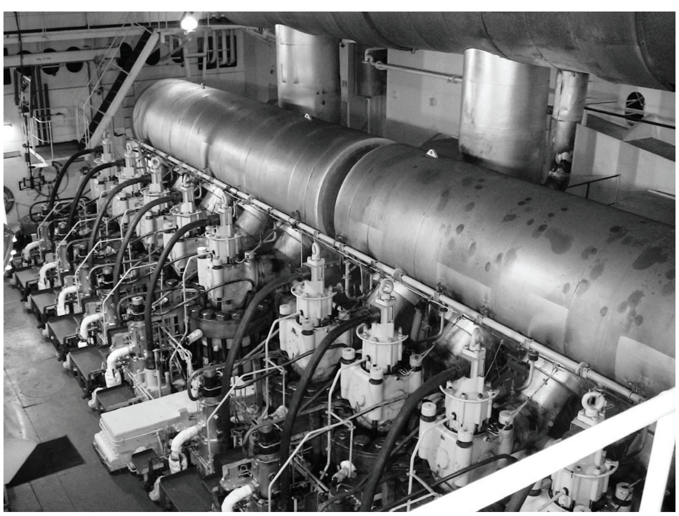

Figure 3. Engine Fuel Efficiency

Viscosity Control

The measurement and control of HFO viscosity is a known requirement within the marine and diesel engine industries. The blending of marine heavy fuel oils in terminals and on-board fueling barges often leaves the buyer and/or supplier without a clear picture of the fuel quality. Continuous viscosity measurement aboard each barge or vessel can provide dynamic, real-time validation of fuel quality, thereby reducing the number of bunker disputes.

Micro Motion viscosity meters, developed in close cooperation with leading engine manufacturers, can measure both dynamic and kinematic viscosity. This is critical for applications involving fluids with varying densities such as light and heavy oils. These meters measure not only kinematic viscosity at injection temperature but also provide a range of other quality factors including density at injection temperature and at the centrifuge temperature. The viscosities measured can be used to calculate both versions of the ignition index and fuel grade viscosity requested by engine manufacturers.

Summary

Micro Motion direct mass flow and viscosity measurement offers many benefits to marine fuel management operations. Inherent advantages, such as multi-variable measurement and no moving parts are shared among all Coriolis meters. However, the challenges for fuel bunker measurement are clear and the ability to maintain ongoing measurement performance and reliability in the presence of entrained gas or two-phase flow is not characteristic of all Coriolis meters. It is critical, therefore, to ensure any measurement technology is able to deliver accurate measurement in the presence of highly variable process conditions. Micro Motion Coriolis offers unmatched technical performance in harsh conditions and field-proven operation of Coriolis measurement in a range of fuel bunkering applications.

Coriolis Operation Principle

Coriolis meters operate by vibrating one or more flow tubes at the resonant frequency. Density is measured directly from this natural frequency, and mass flow is found from asymmetric tube displacements caused by the Coriolis force. A simple, interactive tool for learning how a Coriolis meter works can be found at: http://www.emersonprocess.com/micromotion/tutor/index.html

About the Authors

Joel Weinstein is a research and applications engineer for Micro Motion, a division of Emerson Process Management, which developed and manufactures the Coriolis flow meter. Dr. Weinstein has recently completed a five-year joint research project with the University of Colorado focused on improving Coriolis measurement with entrained gas for difficult industrial applications such as fuel bunkering.

Ashley Hayes is a Marine Business Development Manager for Micro Motion. Ashley has held positions in the process control and automation industry for over 20 years. Ashley's experience has focused on the proper application of process instrumentation in all industries, to provide specific improvements in asset management, reliability, efficiency and costs reductions.

Micro Motion, Inc. USA
Worldwide Headquarters
7070 Winchester Circle
Boulder, CO 80301
T +1 303-527-5200
+1 800-522-6277
F +1 303-530-8459

Micro Motion Europe
Emerson Process Management
Neonstraat 1
6718 WX Ede
The Netherlands
T +31 (0) 318 495 555
F +31 (0) 318 495 556

Micro Motion Japan
Emerson Process Management
1-2-5, Higashi Shinagawa
Shinagawa-ku
Tokyo 140-0002 Japan
T +81 3 5769-6803
F +81 3 5769-6844

Micro Motion Asia
Emerson Process Management
1 Pandan Crescent
Singapore 128461
Rebuplic of Singapore
T +65 6777-8211
F +65 6770-8003