White Paper

Improving Bunkering Operations By Using Coriolis Mass Flow Meter Technology and Advanced Delivery Platform

EMERSON

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Emerson CBMS

Executive Summary
Accurate and reliable measurement and reporting of marine bunkering is critical for both sellers and buyers, to ensure confidence in the billing process. The unmatched performance and measurement certainty of Coriolis meters has led to them becoming the preferred technology to provide highly accurate and reliable mass flow measurement in bunkering applications. Coriolis forms the basis of the Emerson Certified Bunker Measurement Solution (CBMS), which ensures optimal mass flow measurement performance. This paper looks at how the Advanced Delivery Platform from Minerva Bunkering, combined with the Emerson CBMS, provides users with complete digitization of the bunker profile as well as all documentation, including an electronic bunker delivery note (e-BDN), ensuring an unprecedented degree of bunker delivery transparency and efficiency.

The Importance of Flow Measurement Accuracy
Bunker fuel is an expensive commodity and therefore precise and reliable flow measurement is crucial during custody transfer for both sellers and buyers. Billing is based on mass, and accurate flow measurement helps to ensure that the correct mass of fuel is transferred and creates confidence in the validity of the billing process. This then establishes trust between stakeholders in the fuel supply chain, and reduces the chances of a dispute that could cause damage to important commercial relationships. However, whilst high flow measurement accuracy during custody transfer is vital, it is challenging to achieve.

Measurement Methods
Many vessels still rely on the traditional method of determining the amount of fuel transferred during custody transfer, which is to perform manual tank sounding measurements. In this method, conversion tables and density measurements are used in conjunction with a level measurement by dip tape to calculate the total mass of bunker fuel delivered. However, there are several factors that can affect the accuracy of this calculation, such as the strike plate location, the dip tape, the accuracy of the

conversion tables, the tank straps, movement of the ship, the temperature inside the tank and human error. This method is also inconvenient, labor-intensive, and time-consuming, as it requires manpower and multiple measurements, and there are safety risks for personnel performing these measurements.

An alternative method to manual sounding is to use volumetric flow meters, but the measurements provided by these devices must be corrected for temperature, pressure and density conditions to derive the mass flow rate. The need for these calculations introduces the risk of errors that can significantly affect the accuracy of the measurements and lead to disputes between the fuel seller and the buyer.

For an in-depth assessment of the inherent uncertainties in volumetric measurement systems, please refer to the Emerson white paper *Improving Marine Bunker Barge Performance Using Coriolis Meter Dynamic Flow Measurement To Eliminate Static-Volume Errors.*

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Certified Bunker Measurement Solution

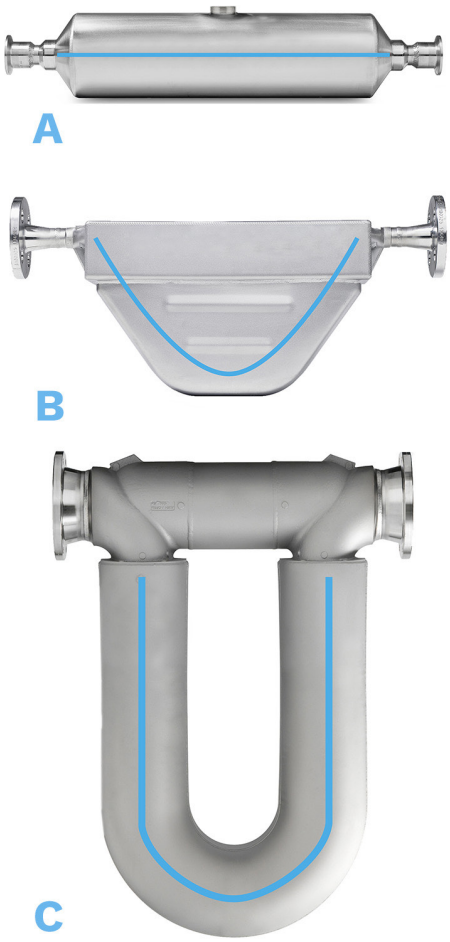
The poor accuracy of traditional flow measurement methods has led to increasing interest in Coriolis mass flow measurement for marine applications. Since Emerson pioneered the first Coriolis flow meter in 1977, the technology has revolutionized the industrial flow measurement market. The use of Coriolis technology has become mandatory in the port of Singapore and is gaining popularity in other major ports around the world. Coriolis meters are easy to install, and a single device provides direct, real-time measurement of mass flow rate, density, temperature and batch totals. In addition, Coriolis meters used to simultaneously calculate volume, which eliminates the need for mathematical conversions and their potential for costly errors. Process variation is automatically incorporated into the results, eliminating the effects of stratification. Flow and density accuracies to within ±0.1% (non-aerated fluids under laboratory conditions) result in unmatched performance and measurement certainty, thereby reducing the number of disputes over delivery quantities and making Coriolis technology an attractive alternative to static volume-based measurement.

Although Coriolis technology is well suited for fuel bunkering applications, there are certain factors that should be considered when selecting a mass flow measurement solution, to ensure optimal performance. These include the ability to handle entrained gas, and good performance in the measurement of viscous fluids.

The Emerson Certified Bunker Measurement Solution (CBMS) is a traceable, transparent, mass-based measurement system that includes a Micro Motion ELITE® Coriolis meter, a transmitter with Marine Bunker Transfer Package, and a bunker delivery ticket printer. Whether installed on a vessel, barge, or at a terminal, the Emerson CBMS monitors the bunker delivery, reports final totals, and provides a ticket that can be used for custody transfer. It is a globally-certified package that meets the requirements of the European Measuring Instruments Directive (MID) and the Maritime and Port Authority of Singapore (MPA) SS 648 standard, and can successfully handle both entrained gas and viscous liquids.

Entrained Gas

The accuracy of flow meters is affected by aeration, which is when gas becomes entrained in the fuel because of a variety of operational practices. To mitigate the challenge of gas entrainment in bunker line, a U – Shaped flow meter is used. The U-Shaped design lowers the natural resonance frequency reduces the likelihood of decoupling in the tubes and therefore minimizes the effect of gas entrainment. The Emerson CBMS also includes a diagnostic that monitors aeration against the MID limit, which is the maximum cumulative uncertainty that can be tolerated in a bunker transfer, as defined by the Organization of Legal Metrology. If the diagnostic reports that aeration for the total bunker exceeds the MID limit, the bunker is not custody transfer certified to ±0.5%.



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The bunker ticket includes the final value of the aeration diagnostic. The aeration diagnostic provides real-time feedback to the operator during every bunker transfer, so that improper procedural causes of aeration can be quickly identified and eliminated. When the Emerson CBMS is properly implemented and MID and/or MPA SS 648 custody transfer regulations are followed, the meter mass total is certified to within ±0.5% of the true mass total. This is far more accurate than static volume-based solutions in use today.

Measuring Viscous Liquids

Bunker fuel is thick and viscous, and in many cases must be heated before it will flow. With no moving internal parts to clog or wear, Coriolis meters offer advantages over mechanical flow measurement devices. Importantly, although Coriolis meters are calibrated using water, this calibration directly transfers to the measurement of any fluid – from gases to viscous oils. Also, mass of oil is conserved regardless of changing temperature and pressure, making fluid correction tables unnecessary. The result is an easy-to-use, robust device that is capable of both accurate measurement and lasting performance in the most challenging of conditions.

Fuel Type Variation

Environmental regulations put in place by the International Maritime Organization (IMO) mean that many bunker vessels must now be able to operate with multiple fuel types. The properties of different grades of marine fuel can vary a lot in terms of density, viscosity, operating temperature and sulfur content, and this can impact mass flow meter accuracy.

Before a mass flow meter can be used for custody transfer, it is necessary to carry out a ‘zero setting’ to ensure that it is tuned to the installation to avoid zero offset errors. With each change in fuel type, normally a new zero setting of the mass flow meter needs to be done to suit the new fuel type. Without checking the zero value, it will be difficult to determine whether the measurement is still within the certified ±0.5% uncertainty.

In order to comply with the IMO regulations and still achieve operational flexibility, some operators have gone ahead with multiple mass flow meter-based custody transfer systems. However, most vessels and bunker tankers are not designed to handle multiple grades of fuel at one time. The operators of such vessels and bunker tankers are expected to change bunker fuel type depending on demand, and this will require re-certification of the system, leading to downtime and unnecessary costs.

The Emerson CBMS overcomes the challenge of switching between multiple marine fuels. This solution can measure any type of marine fuel without the need for adjustments, meaning that vessels and bunker tankers outfitted to handle different types of fuel can now operate using only one bunker measurement system. The unique and patented Micro Motion meter U-shaped design helps to ensure that the zero set during the initial commissioning stage does not need to be re-certified when changing fuel type.

This means that operators with vessels or bunker tankers fitted with an Emerson CBMS can utilize the system to load and deliver multiple fuel types without the need for re-certification and without having to worry about compliance or accuracy.

Delivery Documentation
Upon completion of a bunker delivery, the seller and buyer can print the bunker ticket. The printed ticket includes the time and date, the total amount of fuel transferred, and other relevant data. The seller must also provide a Bunker Delivery Note (BDN) to the buyer, who must then compare the BDN with the ticket. The BDN contains specific information about the delivery and must remain on the vessel for three years afterwards, for inspection purposes. The delivery information contained in the BDN includes the name and IMO number of the receiving vessel, the port at which the delivery took place, the date of the delivery, the name and contact details of the seller, the name of the fuel product delivered and its quantity, density and sulfur content.

BDNs are typically still completed with pen and paper but this process seems increasingly archaic in the modern digital age where technological changes are permeating and transforming many areas of industry. This reliance on a paper-based system of documentation gives rise to a number of issues. The manual process is slow, typically taking two to three hours; prone to entry errors, which can lead to costly delays; and it makes the analysis of historical data difficult to achieve. There is also the chance of documents being illegible, incomplete, lost or damaged, which can have serious legal consequences.

The Advanced Delivery Platform (ADP)
Minerva Bunkering is an international marine fuel logistics company that markets and physically supplies fuel and lubricants to ships in port and at sea. The company wanted to digitize the bunkering process, to make it faster, more reliable and more efficient, whilst still ensuring legal compliance. It therefore developed an innovative digital solution – the Advanced Delivery Platform (ADP). The ADP is a proprietary operating system that delivers 360-degree verified transparency on the quality and quantity of bunker deliveries, as well as industry-leading digital documentation and reporting capabilities. Emerson also played a vital role in the development of the ADP, working closely with Minerva on elements of the platform's passive design compatibility with the Emerson CBMS.

The ADP comprises three constituent parts:
- Sentinel – internally designed hardware to transmit real-time mass flow and other advanced meter data.
- ADP Onboard – a software solution that digitizes the process of creating bunker delivery documents and streamlines with pre-populated and automated data entry, resulting in estimated time savings of two to three hours per operation.
- ADP Online – a customer portal with pre-delivery, delivery and post-delivery data viewable real-time from anywhere.

Benefits of the ADP
Harnessing the precision of Emerson's certified Coriolis mass flow meter measurements and leveraging communications technology to digitize and streamline onboard documentation, the ADP provides users with an unprecedented degree of bunker delivery transparency and efficiency, reducing both risk and costs. The platform provides valuable insights into all details of bunkering operations, including the quality of fuel delivered, operational timelines, and the quantity received – all in real-time and able to be viewed from anywhere via the customer portal. The customer portal is a foundation upon which additional functionalities can be plugged in, improving the platform's value proposition. These additional functionalities can include invoicing, operational updates, bunker planning tools, bunkering analytics, requests for quote, price indications and emissions tracking.

The ADP enables onboard documentation to be conducted entirely digitally on both the supplying and receiving vessels via the networked application, resulting in hours of saved time and the elimination of human errors from manual entries. Back-end integration with customer software systems is supported via an application programming interface (API) to enable streamlined invoicing and business intelligence. Furthermore, the platform's audit functionality provides complete transparency into every ton of fuel loaded onto and discharged from the supply vessel utilized in each customer delivery.

Procedural Improvements With the ADP
The ADP Onboard software solution digitizes and streamlines the process by pre-populating and automating data entry via APIs to feed fuel characteristics and reference information into the delivery documents directly. The ADP enables all bunkering documentation and approvals to be carried out via connected devices (bridge computers, tablets, smartphones) of the respective vessels communicating securely over the ADP Intranet. The intuitive software follows all the requisite approvals and acceptances of paper documentation, but with increased efficiencies of automation and digitization.

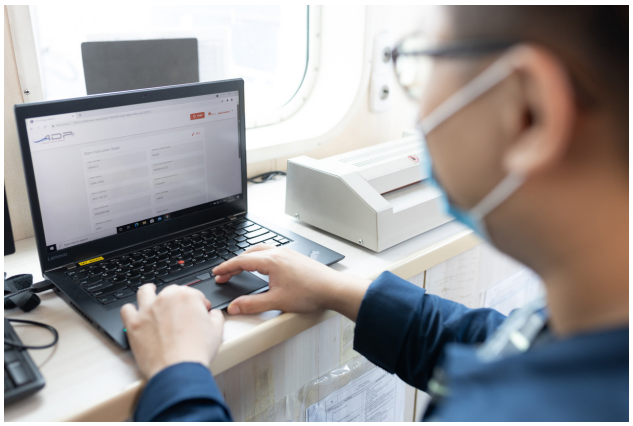
The suite of digital bunkering documents created by the application includes:
- Sampling procedures.
- Safety/pollution checklist.
- Handling procedures.
- Bunker analysis report.
- e-BDN.

The ADP Online Client Portal provides secure, permissioned URL access for clients to view and access pertinent information and metrics on their bunker deliveries via a real-time interactive bunker management dashboard. Clients can view current and historical bunker deliveries and drill-down into information pertaining to their deliveries:
- e-BDN and full suite of on-board documentation.
- Full barge audit record, including independent surveyor reports and mass flow meter profiles.
- Operational metrics and timeline of the delivery.
- Performance ratings for each delivery.

Clients can view certified mass flow meter (MFM) delivery profiles displaying five key registers of data. The delivery profile can be customized as desired by the client to present any of the approximately 100 registers recorded.

The ADP provides clients with the unique transparency of a full barge audit cycle to trace the flow of every barrel of fuel passing through the delivery barge:
- Starting with pre-loading Remaining on Board (ROB) quantity and loaded quantity as per third party surveyor reports.
- Each inflow and outflow quantity verified by MFM delivery profiles (anonymized when involving other clients).
- Completion of the audit cycle prior to next loading with ROB quantity as per third party surveyor.

As barge operators increase their drive for efficiency, several other functionalities will be required.
The current pipeline of enhancements includes:
- API integration with invoicing and business intelligence software.
- Full inquiry through to fixture over the platform.
- Scheduling communications and workflow (i.e., real-time scheduling and ETA updates, delay alerts, etc.).
- Greenhouse gas emissions calculation and offset sales.
- Trade credit and payments management.



Case study: Minerva's ADP and Emerson's CBMS in practice

In November 2020, a Proof of Concept (POC) delivery was carried out by Minerva Bunkering which engaged the cooperation of the Singapore MPA, Emerson and Hafnia to demonstrate a successful deployment of ADP hardware and software across a complete barge cycle (loading through deliveries).

Prior to the installation of the ADP, the process of collecting data was a manual one. First the flow meter was zeroed using the local operator interface. Pumping would then begin, and the information would be displayed on the local display for the crew to view. Once the bunkering had been completed, the transmitter would print off a paper ticket constituting the fuel quantity measurement. Under current industry standards this still constitutes the certified bunker measurement. All of the information would then be transferred and duplicated by hand onto the separate documents as per the barge processes and eventually an invoice would be produced and presented to the receiving vessel. These processes were manual and time-consuming. Hence, there was an obvious need for innovation, automation and digitization.

The POC utilized a Minerva bunkering tanker, M/T Venus, operating an Emerson CBMS in compliance with SS 648, and Hafnia's M/T BW Amazon. Minerva worked with Emerson to devise a certifiable data transmission protocol to ensure data coming from the mass flow meter and utilized in the ADP application is verified and passively transmitted.

During the bunkering operation, the ADP hardware was connected passively to the Emerson CBMS. This allowed all live and totalized data to be read and exported across the ADP application seamlessly to complete the bunkering operation efficiently and accurately. Also, to relay in near real-time the results and details of the operation to the ADP Online application, for Hafnia regional and head office management oversight and review.

Key benefits demonstrated by the POC include:
- Complete transparency over quality and quantity with access to the live continuous bunker profile.
- Intuitive onboard software application and networked communication protocol facilitating real-time visibility into operations and exchanges of signatures and approvals without physical contact of crews.
- Saving on non-pumping time alongside of greater than two hours.
- Full audit visibility into the barge cycle showing MFM profiles and third-party surveyor reports to trace the flow of all product passing through the delivery barge.

Operational results with ADP

During the POC, the amount of time taken for total bunker operation was measured. The pump and bunkering flow rate were monitored and observed to be a similar flow rate to the typical bunkers prior to ADP installation. The appreciable difference was in the efficiency of pre- and post-pumping processes, including documentation, the duration of which was reduced by more than two hours. In addition to the reduction in time spent completing the bunker, digitized reports and bunker profiles were made available instantaneously. Hafnia management was able to view all details of the delivery and digital documentation upon completion of the operation via ADP Online.

Following the successful POC, Minerva secured a long-term commitment for ADP-enabled bunker deliveries with Hafnia, initially covering the markets of Amsterdam, Rotterdam and Antwerp (ARA), Fujairah and Singapore.

"We have been vocal about wanting to see this sort of technology and process applied to other major ports in addition to Singapore. A supplier has stepped up to the task, and we are here to support it as promised. It is a big step towards more efficient operations for the industry at large, and will certainly be positive for vessel operations in these ports."
- Peter Martin Grünwaldt, Hafnia's Vice President of Bunker Procurement.

Conclusion

One of the primary goals of bunker delivery system operators is to achieve consistent balance of their inventory levels. Micro Motion Coriolis flow meters are rapidly being adopted for use in bunker deliveries because they provide the accurate measurements needed to achieve inventory balance and because they can identify any steps in bunkering procedures that are resulting in entrained air.
The Emerson CBMS, whilst being able to operate standalone, can also be seamlessly integrated with the ADP software. The ADP enables all the data collected by the mass flow meter to populate effortlessly into digital bunkering documentation and reporting. In addition, the integration between the CBMS and the ADP allows the supplier bunker vessel and receiving vessel to gain insight into the bunkering operation in real-time with complete transparency over product delivered. Moving forward, digitization of the complete supply chain will not only improve efficiency and transparency, but will also lay the groundwork for regulatory updates, including e-BDNs and paperless transactions.

About Minerva Bunkering

Minerva Bunkering is an international marine fuel logistics company that provides fuel and service solutions to ships in port and at sea. The company operates the industry's largest physical supply network and serves over 600 customers across all major commercial shipping sectors including container ships, dry bulk carriers, cruise ships, tankers, and ferries. Minerva Bunkering is a 100-percent-owned subsidiary of Mercuria Energy Group, one of the largest privately-held energy and commodities companies in the world. For additional information, please visit www.minervabunkering.com

About Emerson's Marine Solutions

Emerson is a world-leading provider of marine solutions with engineering excellence, decades of industry experience and global presence supporting any ship anywhere. All marine systems and solutions are designed especially for the harsh marine environments, engineered and manufactured in-house by our skilled teams of marine engineers. Emerson is well-known in the industry and has more than 50 years' experience with a large installed base and covers well-known marine brands such as Rosemount, Micro Motion and Damcos. Supporting marine customers from a global network of sales and service hubs along the maritime highway.

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