White Paper

REFINING BUNKER BARGE PERFORMANCE USING CORIOLIS METER TECHNOLOGY AND THE ADVANCED DELIVERY PLATFORM

MINERVA

EMERSON

Executive Summary

Accurate, on-the-spot measurement and reporting of marine bunkering is critical for both cost control and operational efficiency. The combination of Emerson Certified Bunker Measurement Solution and Minerva's Advanced Delivery Platform (pat. pend.) provides highly accurate data with complete digitization of the bunker profile as well as all documentation including an e-BDN. In addition, the continuously streamed data allows the receiver to view pre-delivery and post-delivery data real-time both onboard and remotely. Depending on the implementation, the bunker measurement is certified by Nederlands Meetinstituut (NMi), the notified body for testing to the guidelines of the European Instruments Directive (MID) and Issuing Authority for OIML (International Organization for Legal Metrology). In the case of the port of Singapore MPA SS648.The Micro Motion mass flow meter meets the OIML standard R117-1 and the overall solution meets MID Directive 2004/22/EC Annex MI-005

Introduction

Many barge practices in the bunkering industry employ tank-based measurement systems that provide static volumetric measurements. The volume totals are corrected to reference temperature and pressure (standard volume). Depending on local requirements, the volume totals may then be converted to mass. The required temperature and pressure measurements may be automatic or manual. Density values are obtained by sampling and laboratory analysis.

Read more about mass vs volume calculation in https://www.emerson.com/documents/automation/white-paper-improving-marine-bunker-barge-performance-using-coriolis-meter-dynamic-flow-measurement-to-eliminating-static-volume-errors-micro-motion-en-66788.pdf

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 technology provides measurement of mass flow rate, volume flow rate, density, temperature and batch totals – all from a single device. Flow and density accuracies of ±0.1% (non-aerated fluids under laboratory conditions) results in unmatched performance and measurement certainty, making Coriolis technology an attractive alternative to static volume-based measurement.

While Coriolis measurement is well suited for fuel bunkering, additional factors are required to be met for optimal performance.

These include:

- The ability to handle entrained gas
- Good performance in the measurement of viscous fluids.

Minerva Bunkering has leveraged its status as a leading integrated physical bunker supplier to develop a bespoke proprietary operating system – the Advanced Delivery Platform (ADP) - that utilizes these Coriolis measurements together with additional hardware and software to optimize transparency and efficiency in the bunker fuel delivery process.

This paper looks in detail at how the two technologies work together to provide an industry leading solution that sets the benchmark for the future of bunkering.

Emerson Certified Bunker Measurement Solution

The Emerson CBMS is a combination of a Coriolis sensor, a software application, specialized calibration, installation and support services, and procedural requirements. The package addresses all of the additional factors noted above.

Entrained gas

Meter accuracy is affected by aeration – air or gas entrained in the fuel. Aeration may occur as a result of a variety of operational practices such as pumping.

To address aeration, the Emerson Certified Bunker Measurement Solution includes a diagnostic that monitors aeration against the MID uncertainty limit. If the diagnostic reports that aeration for the total bunker exceeds the MID limit, the bunker is not custody-transfer certified to 0.5%. The bunker ticket includes the final value of the aeration diagnostic.
The aeration diagnostic provides immediate feedback on every bunker to the operator so that improper procedural causes of aeration can be quickly identified and eliminated.

When the Certified Bunker Measurement Solution is properly implemented and MID and/or MPA SS648 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

Heavy fuel oil or 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 down, Coriolis meters offer advantages over other mechanical flow measurement devices. Even more important, Coriolis meters are calibrated on water, which 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.

As with all other flowmeters, there are various influences on Coriolis meters for which compensation is required. For example, as the temperature of the process fluid changes, the stiffness of the flow tubes changes, and this in turn influences the mass flow measurement.

An integral temperature measurement is used to compensate for this effect and produce an accurate measurement over a broad range of temperatures.

Emerson regularly employs independent third-party testing of its Micro Motion Coriolis mass flow meters to ensure performance on difficult fluids. Data from the SPSE laboratory in France shows excellent performance from the Micro Motion ELITE® Series Coriolis meter on widely varying fluid types, including fuel oil – all from a single water calibration. An MID certificate has been awarded for ±0.2% mass accuracy on liquids based on settings determined during water calibration.

"Mass in Air" vs. "Mass in Vacuum"

"Mass in vacuum" is the true mass of an object. Coriolis meters report "mass in vacuum". However, many mass measurements values, including tank-derived values, actually represent "mass in air". "Mass in air" is the mass of an object as affected by the force of gravity (i.e., the weight) and the buoyancy of the surrounding medium (typically air).

This factor is a result of the density of air, which varies with temperature, pressure, humidity and altitude.

The equation below shows the relationship between "mass in air" and "mass in vacuum". Assuming the following:

Density of air: 1.2 kg/m3
Density of fluid: 990 kg/m3

This equation yields the following conversion factor:
Mass in air = Mass In Vacuum x 0.9987

For example, the mass total reported by the meter is 2000 mT. For a more accurate comparison to the mass total derived from tank measurement, multiply 2000 mT by 0.9987 = 1997.7 mT. (Looking at it the other way, the "mass in vacuum" measurement is the "mass in air" measurement multiplied by 1.0013.)

Emerson Coriolis Mass-Based Measurement

The Coriolis meters measure mass directly, so no volume-to-mass conversion is required. The meters are calibrated at the factory in mass units, which are not affected by density. The effects of temperature on sensor response are eliminated via automatic temperature compensation using the integral temperature measurement, that is located inside the flowmeter. As a result, mass measurement is essentially unaffected by process conditions and no additional inaccuracy is introduced by conversion from volume to mass.

Volume data

In addition to mass measurement, Micro Motion mass flow meters simultaneously calculate volume, using real-time mass, temperature, and density measurements. Process variation is automatically incorporated into the results, eliminating the effects of stratification. Real-time temperature is also used in the on-board conversion to volume at reference temperature.

In addition to providing more accurate and dynamic volume data, the Emerson solution eliminates the time, cost, and effort involved in sampling, laboratory analysis, and post-analysis calculations.

Cumulative uncertainty in Coriolis systems

Cumulative uncertainty is small or non-existent in Coriolis mass-based measurement:

- A single device is used for mass, density, and temperature, eliminating multiple device issues.
- Volume is calculated from real-time process data, eliminating uncertainty related to sampling, laboratory procedures, and conversion tables.

In summary, the standards governing bunkering in the marine industry require bunker delivery notes to state quantity in mass and ensure all measurements that are given are accurate within 0.5%. Coriolis meters are not only a direct mass measurement instrument, they also have the capability to maintain high levels of accuracy during the bunkering operation.

Advanced Delivery Platform

The Advanced Delivery Platform (ADP) is an innovative technology platform developed by Minerva to provide a fully transparent and efficient bunker delivery service, reducing cost and risk for receivers.

Custom-built IoT hardware enables two bespoke software applications, ADP onboard and ADP online, to deliver Minerva's customers 360 degree verified transparency on quality and quantity of bunker deliveries as well as industry leading digital documentation and reporting capabilities.

Following a successful Proof of Concept (POC) achieved in Singapore (see Case Study section below), Minerva secured a long-term commitment for ADP enabled bunker deliveries with Hafnia initially covering the markets of ARA, Fujairah, and Singapore.

The ADP's digitization of the bunkering process from pre to post-delivery, enables further expansion of the value proposition to stakeholders including:

- Tailored client functionality with API integration to invoicing and business intelligence software
- Inquiry through fixture over the platform
- Custom client reporting
- Scheduling and workflow
- Real-time digital reporting to port and customs authorities

Case Study – Minerva's Advanced Delivery Platform 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).

The POC utilized a Minerva bunkering tanker, M/T Venus, operating an Emerson Certified Bunker Measurement Solution 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 (figure 1) 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.

With the successful POC completed, Hafnia and Minerva entered into a long-term supply agreement utilizing the ADP at fuel premium levels that reflect the cost savings and value-add of the service.

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 2 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.

Previous Process

Prior to the installation of 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 the print off a paper ticket constituting the fuel quantity measurement. This still under current industry standards constitute the certified bunker measurement.

Then all of the information would 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 is an obvious need for innovation, automation, and digitalization.

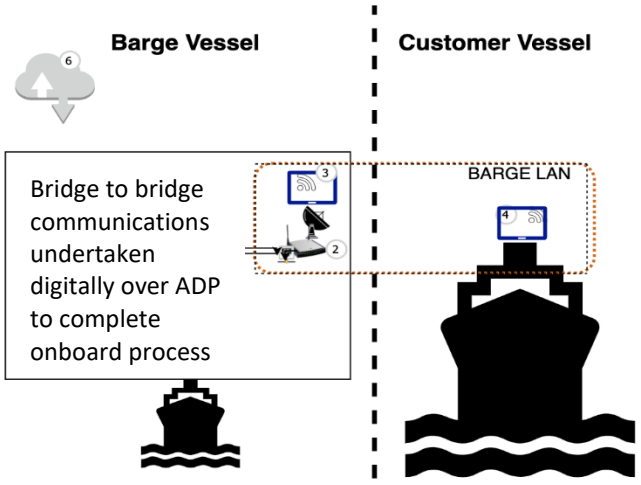

Figure 1. Picture summary of system architecture

Procedural Improvements with the ADP

The ADP Onboard (figure 2) 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, while also facilitating social distancing measures between crews.

The suite of digital bunkering documents created by the application includes:

- Sampling Procedures
- Safety/Pollution Checklist
- Handling Procedures
- Bunker Analysis Report
- e-BDN

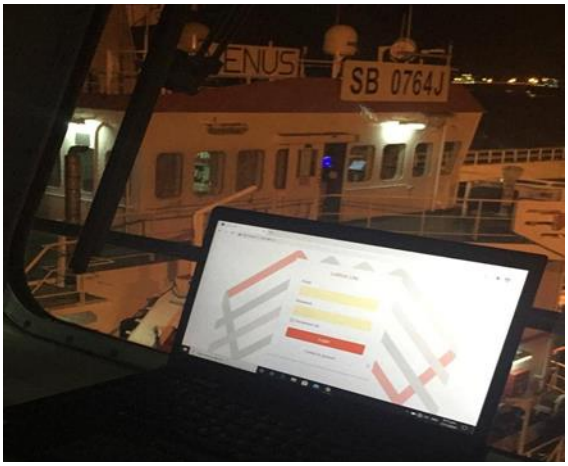

Figure 2. Receiving vessel captain logs into ADP Onboard for POC delivery

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 (figure 3).
- Operational metrics and timeline of the delivery.
- Performance ratings for each delivery.

Clients can view certified mass flow meter (MFM) delivery profiles displaying 5 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 enables clients 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.

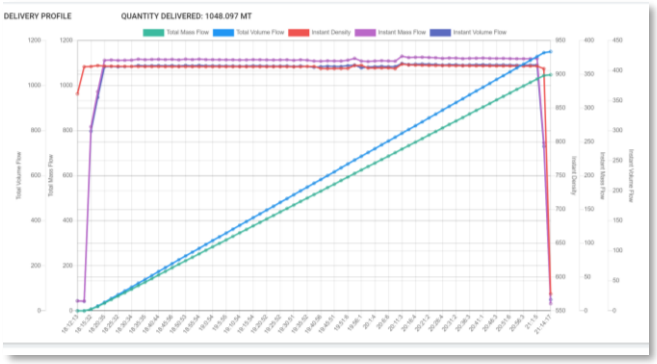

Figure 3. Y-axis is the total mass flow, mass flow rate and density, x-axis is time. Minerva's M/T Venus collected all of the key bunker parameters using Emerson mass flowmeter

As barge operators increase their drive for efficiency several other functionalities will be required.

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.). (figure 4).
- GHG emissions calculation and offset sales.
- Trade credit and payments management

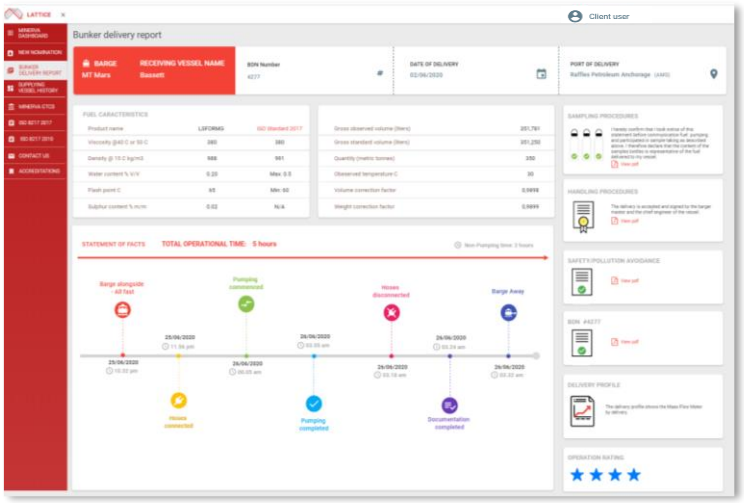

Figure 4. Screen shot of scheduling and communications

Operational results with Advanced Delivery Platform (ADP)

During the POC the amount of time taken for total bunker operation was measured. The pump and bunkering flow rate were monitored and was 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 2 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.

"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

Figure 5. Screen shot of electronic – Bunker Delivery Note from ADP system

Conclusion

One of the primary goals of bunker delivery system operators is to achieve consistent balance of their inventory levels. Micro Motion Coriolis flowmeters 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 Certified Bunker Measurement Solution 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 Certified Bunker Measurement Solution and 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, it will also lay the ground work for regulatory updates including electronic bunker delivery notes and paperless transactions. (Figure 5)

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 at our factories in China, Sweden and Denmark by our skilled team 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, Damcos, Micro Motion and Keystone. From the marine HQ in Naestved, Denmark as well as from a global network of sales and service hubs along the maritime highway,

About Minerva / Mercuria

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 procures product in bulk from diverse sources and delivers to 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.

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