

On-Board Testing to Mitigate Cold Corrosion Damage

Background

The implementation of the IMO 2020 sulfur regulations significantly reduced the allowable sulfur content in marine fuels from 3.5 wt% to a global cap of 0.5 wt%. As a result, most vessels have transitioned from High Sulfur Fuel Oil (HSFO) to Very Low Sulfur Fuel Oil (VLSFO) or to other distillate fuels such as Marine Gas Oils or Marine Diesel Oils.

While these changes have reduced the prevalence of traditional sulfur-driven cold corrosion, new operational challenges have emerged as a result. Modern marine engines must now operate efficiently across a wider range of fuel types, each with distinct combustion characteristics, cleanliness profiles, and unique lubrication requirements.

Frequent fuel switching, such as when entering and exiting Emission Control Areas (ECAs), can introduce combustion and lubrication performance instabilities. These transitions may lead to increased deposit formation, reduced engine cleanliness, and, in some cases, accelerated wear of critical engine components.

As a result, optimizing cylinder lubrication feed rates has become a critical factor in maintaining engine cleanliness, minimizing deposit formations, and preventing abnormal wear across multiple fuel and operating conditions.

Challenge

Maintaining optimal cylinder lubrication feed rates under varying fuel and operating conditions, such as slow steaming, has become increasingly complex. Operators must balance lubrication to ensure sufficient protection against wear, while avoiding any unwanted deposit formation that can compromise the engine. Improper lubrication practices carry significant consequences. Over-lubrication can contribute to deposit buildup, and increased operating costs, while under-lubrication increases the risk of accelerated wear and damage to cylinder liners and piston rings. A key challenge lies in accurately assessing cylinder conditioning and scrapedown samples in a timely and consistent manner. Traditionally, this has been achieved through laboratory-based testing and onboard wet chemistry methods. While effective, both approaches can be time-intensive and subject to operator variability and interpretation, especially for time-sensitive tests.

Lab testing can take days to weeks for results, limiting the ability of operators and engineers to respond to

rapidly changing conditions onboard. As a result, cylinder lubrication decisions are made without the aid of real-time insight, increasing the risk of suboptimal feed rates. This lack of timely, objective data can lead to accelerated wear, deposit formation, and in severe cases, damage to engine components. Unintended maintenance and repair activities are both costly and operationally disruptive, contributing to increased downtime.

Solution

To address these challenges, a real-time, onboard approach to cylinder condition monitoring is required. One that enables the crew to make timely, data-driven decisions on their lubrication under these fuel and operating conditions.

MobilSM Cylinder Condition Monitoring, developed by ExxonMobil as a part of its cylinder condition monitoring service offering, utilizes an onboard X-ray Fluorescence (XRF) technology to provide rapid, multi-element analysis of cylinder lubrication oil. The system utilizes an Energy Dispersive X-ray Fluorescence (EDXRF) device supplied by X-ray Optical Systems (XOS) as the analytical hardware component, enabling high-performance analysis in a rugged, shipboard-ready platform.

The system enables measurement of key indicators including Total Base Number (TBN), as well as critical wear and contamination elements such as iron (Fe), vanadium (V), chromium (Cr), and calcium (Ca). Designed for ease of use in onboard environments, the system requires roughly 40mL of sample, which is dispensed into a bottle from the scavenge space of each cylinder. The bottle is then sealed with a premade cap and inserted into the analyzer. Once the operator selects the appropriate measurement parameters and closes the lid of the analyzer, analysis begins. Results are delivered in minutes, enabling rapid assessment of cylinder lubricant conditions and allowing for quicker more informed adjustments. In addition to lubricant analysis, the system can also provide analysis on sulfur in marine fuels, furthering the operator's ability to verify regulatory compliance and incorporate vessel fuel characteristics into lubrication strategies. This additional visibility enables more precise feed rate optimization, particularly during cylinder oil and fuel switching operations.

*The term "ExxonMobil" used in this document refers to ExxonMobil Marine Limited and/or another relevant ExxonMobile selling affiliate. Nothing in this document is intended to override or supersede the corporate separateness of local entities. Responsibility for local action and accountability remains with the relevant local ExxonMobile-affiliate entities.

Integrated reporting capabilities with MobilSM CCM further enhance decision-making by presenting measurement data alongside insights, helping onboard engineers and crew interpret analytical results, aiding in efficient, consistent, and safe operational adjustments.

Compact, rugged, and designed for shipboard use with minimal maintenance MobilSM CCM offers a rapid non-destructive solution for continuous monitoring. By enabling faster, more accurate analysis of cylinder lubrication, operators, and engineers can improve engine cleanliness, reduce wear, and minimize maintenance costs and unplanned downtime.

Report Generation

The report generation interface transforms raw cylinder condition data into clear, actionable intelligence by integrating visual dashboards with structured analysis. As shown in the adjacent figures, users are presented with a consolidated view of equipment status, oil condition, and detailed cylinder-level insights within a single report, eliminating the need to interpret fragmented data sources.

The top panel provides an immediate snapshot of cylinder health, clearly identifying safe, warning, and alert conditions across both equipment and oil status. This enables engineers to quickly isolate anomalies—such as Cylinder 5 entering an alert state—without manual data review. Supporting this, the trend-based visualization (TBN vs. Fe) offers a deeper analytical context, allowing users to assess wear progression and lubricant performance over time, and determine whether conditions are stabilizing or deteriorating.

At a more granular level, the detailed cylinder analysis highlights specific deviations relative to OEM thresholds, reinforcing where corrective action is required. By linking these insights directly to recommended feed rate adjustments, the system enables operators to move from observation to action with speed and confidence. This integrated approach ensures that decisions are not only data-driven but also aligned with best practices for engine protection and efficiency.

Within the remainder of the report is a further breakdown of additional parameters such as chromium (Cr) vs. engine hours, vanadium (V) vs. engine hours, followed by an additional results summary.



MobilSM Cylinder Condition Monitoring Report

Cyl 1: Safe	Cyl 2: Safe	Cyl 3: Safe	Cyl 1: Safe	Cyl 2: Safe	Cyl 3: Safe
Cyl 4: Safe	Cyl 5: Alert	Cyl 6: Safe	Cyl 4: Safe	Cyl 5: Safe	Cyl 6: Safe
Cyl 7: Safe			Cyl 7: Safe		

Equipment Status

MAN Energy Solutions - 7560ME-G110.5

Oil Status

Exxon Mobil - Mobilgard 540 AC

Situation and Action:

- Cylinders 1, 6, 7: Iron level is still low, but approaching the "Alert" level. Continue frequent oil testing for trend analysis. [MAN-SL2023-738]
- Cylinder 5: Elevated iron levels, acceptable for short term operation. Increase oil sampling frequency

Feed Rate Adjustments:

- Cylinders 1, 2, 3, 4, 6, 7: Data suggests to reduce the Feed Rate by 0.05 g/kWh
- Cylinders 5: Data suggests to increase the Feed Rate by 0.05 g/kWh

TBN vs. Fe

Cylinder Details

Cylinder 5 - Some results in OEM alert area

Feed Rate (g/kWh)	1.2	Fe (ppm)	62.13
Cr (ppm)	--	Fe Status	abrasive
V (ppm)	--	TBN (mgKOH/g)	68.79

*Cells containing "--" denote data not detected

*Fe concentration is corrected as "Fe Concentration x Feed Rate" based on [MAN-SL2023-738]. Fe Concentration (ppm) is direct measurement from XRF unit and Feed Rate is as reported by customer.

Situation and Action Details:

- Elevated iron levels detected. The amount of acid generated indicates that it is most likely abrasive wear. We recommend to conduct a scavange space inspection of this/these unit/unit(s) at your earliest convenience to look for both signs and causes of wear. We also recommend to flush sample points for 30 minutes prior to taking samples. This will ensure and residual iron debris at the points will not effect results.

Feed Rate Adjustments:

- Data suggests to increase the Feed Rate by 0.05 g/kWh

1.518.880.1500 • info@xos.com • xos.com



MobilSM Cylinder Condition Monitoring (CCM) is a service developed by ExxonMobil to help optimize cylinder lubrication and engine performance across modern marine operating conditions. Drawing on ExxonMobil's decades of engineering expertise and deep understanding of marine lubrication systems, the service delivers actionable insights that enable crews and operators to make more informed, timely decisions to enhance reliability and efficiency.

MobilSM Cylinder Condition Monitoring combines ExxonMobil's engineering expertise with advanced onboard analysis to deliver accurate, actionable insights into cylinder condition and lubrication performance. With MobilSM CCM, customers benefit from more than just a powerful oil analysis programme – they gain the support

of Mobil, backed by decades of marine experience. The service is enabled using the XRF analyzer supplied by XOS, which provides the physical test unit equipment, servicing and maintenance, and has been with the MobilSM Cylinder Condition Monitoring service from the very beginning, continually innovating and helping ensure that ExxonMobil provides you with the high-quality insights for your engines.

By combining ExxonMobil's expert analysis with high-quality onboard data, MobilSM CCM supports a shift from reactive maintenance to a proactive, data-driven approach. This service provides reliable, real-time insights that help optimize feed rates, reduce component wear, and improve overall engine performance across a wide range of operating conditions.

