

ISSN 2250-1967



MARINE INDIA

ENGINEERS REVIEW

JOURNAL OF THE INSTITUTE OF MARINE ENGINEERS (INDIA)

Volume : 20

Issue : 4

March 2026

₹ 90/-



Dual-Fuel Era:

**Propulsion Breakthrough,
Reliability Lessons, Safety Imperative**



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EDITORIAL

“The measure of intelligence is the ability to change.”

— Stephen Hawking



The signals coming out of World Economic Forum this year were unusually clear for a forum known more for ambiguity than direction. Beneath the familiar rhetoric on resilience and sustainability, a harder economic narrative is taking shape—one that maritime professionals would do well to read early.

First, trade is no longer being discussed as a neutral flow of goods. At Davos, it was framed as a strategic negotiating weapon. This matters because negotiations between European Union and India—driven in large part by the European Commission—are no longer just about tariffs. A prospective EU-India FTA will embed carbon accounting, supply-chain transparency and ESG disclosures directly into market access. For shipping, this means compliance costs will increasingly sit upstream of ports and downstream of charter parties. Vessel efficiency, fuel choice and voyage reporting are quietly becoming trade enablers—or trade barriers.

Second, geopolitical signals from the United States suggest a continued hardening of strategic blocs. The emphasis on “friend-shoring” and critical supply routes implies less tolerance for friction in logistics chains. For maritime operators, this translates into two parallel realities: stable, long-term cargo flows within aligned corridors and heightened volatility elsewhere. Fleet deployment strategies will need to balance political reliability with commercial optimisation—an equation that naval architects and marine engineers are now indirectly shaping through design choices and fuel systems.

Third, the bond market is sending a signal many shipping companies are underestimating. Rising yields are not just a macroeconomic headline; they directly affect fleet renewal, retrofitting decisions and balance-sheet resilience. Higher cost of capital penalises indecision. Owners delaying efficiency upgrades may find that the financing window closes faster than regulatory deadlines approach. Conversely, vessels with credible decarbonisation pathways are already seeing preferential treatment from lenders and insurers.

The combined message is stark: the **margin for strategic delay is shrinking**. Trade policy, geopolitics and **capital markets** are converging faster than regulatory timelines suggest. For the maritime sector, this is **not a future scenario—it is an operating condition**.

March 2026’s challenge for shipping leaders alike is to **read these signals not as distant policy noise**, but as **early indicators of technical, commercial and operational choices** that must be made now. In this cycle, **waiting for certainty may prove costlier than acting on imperfect information**.

The first article talks about engine choices: Low-pressure dual-fuel engines, reshaped by VCR and EGR breakthroughs,

have overturned efficiency and emissions assumptions, making LNG propulsion commercially compelling, regulator-ready and a credible bridge toward ammonia and hydrogen futures.

The second article extending from the last month’s article on LNG ship trials & ship trials -This time the article demystifies LNG carrier gas trials, showing how rigorous cryogenic verification, FGSS logic, and engine commissioning turn a hazardous milestone into a disciplined, repeatable proof of safety and readiness. A must read for all shipstaff and ashore.

The third article highlights some challenges which industry is not taking note and acting upon! A stark warning that relentless vessel utilisation, hollow ISM compliance and exhausted crews are corroding safety from within, urging India to push global reform before maintenance failures and fatigue become irreversible.

The fourth article was discussed in WMTC 2024 and investigates how big data and AI transform reliability-centred maintenance has changed from reactive compliance into predictive value creation, improving machinery uptime, safety, lifecycle cost control and decision-making onboard modern ships. A interesting article for engineers and technical superintendents.

The article maritime accident investigation series - A practical investigation guide showing how boiler blowbacks and fires arise from combustion faults, fuel issues, bypassed safeties and human shortcuts—turning marine steam casualties into structured lessons for prevention. Engineers can easily identify with learnings mentioned in this article.

Under MER Archives April – May 1986

The May 1986 MER(I) edition reflects an industry confronting rising complexity: broader education for engineers, early shipboard digital integration, worsening marine fuel quality and emerging responses. Articles highlight fuel testing’s role in shaping ISO 8217, adaptive “self-thinking” purifiers and Norwegian combustion research—together underscoring the shift toward data, standards and smarter machinery to manage poor fuels and operational risk.

Here is the March 2026 issue for your reading pleasure and intellectual rumination.

Mani Ganapathi Ramachandran

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Printed, Published and Edited by:

Mani Ganapathi Ramachandran on behalf of The Institute of Marine Engineers (India). Published from 1012 Maker Chambers V, 221 Nariman Point, Mumbai - 400 021, printed by Corporate Prints, Shop No.1, Three Star Co-op. Hsg. Society, V.P Road, Pendse Nagar, Dombivli (E) - 421 201. District - Thane

Print Version: **Corporate Prints**

Typesetting & Web designed by:
Kryon publishing (P) Ltd.,
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Dual-Fuel Gas-Burning Diesel Engines for Marine Propulsion

(Part 2: Low-Pressure Gas Admission, Otto-Cycle Combustion and the Variable Compression Ratio Breakthrough)



Kaushik K. Seal
Saptarshi Basu

Abstract

Low-pressure dual-fuel two-stroke engines operating on the Otto cycle have historically been regarded as cost-efficient alternatives to high-pressure diesel-cycle gas engines, albeit with recognised disadvantages in thermal efficiency, load-range robustness and methane slip. This perception has undergone a fundamental transformation following major technological breakthroughs introduced between 2024 and 2025, most notably WinGD's Variable Compression Ratio (VCR) system and MAN Energy Solutions' enhanced ME-GA platform incorporating Exhaust Gas Recirculation (EGR).

This article presents a comprehensive technical and operational analysis of low-pressure Otto-cycle dual-fuel engines, focusing on system architecture, combustion principles, pilot-fuel ignition technology, safety philosophy, control logic, emissions behaviour, operational flexibility, lifecycle economics and future-fuel readiness. Emphasis is placed on the X-DF engine equipped with VCR, which enables real-time compression-ratio optimisation through hydraulic actuation integrated into the crosshead pin. Extensive shop tests and

early commercial sea trials demonstrate methane-slip reductions of approximately thirty percent, fuel-consumption improvements of up to 5.8 percent in gas mode and 6.9 percent in diesel mode and full IMO Tier III NO_x compliance without Selective Catalytic Reduction.

A detailed comparison with high-pressure ME-GI engines shows that low-pressure Otto-cycle engines—especially when equipped with VCR—have closed or reversed the historical efficiency and emissions gap while retaining a fourteen to eighteen percent capital-cost advantage. With typical payback periods ranging from one to fourteen months, Variable Compression Ratio emerges as one of the fastest-return decarbonisation investments available to shipowners and a critical enabler for the transition toward ammonia, hydrogen and other zero-carbon fuels.

Keywords: Low-pressure dual-fuel engines; Otto cycle; ME-GA; X-DF; Variable Compression Ratio; methane slip; EGR; iCER; LNG propulsion; FuelEU Maritime; EU ETS; lean-burn combustion; marine decarbonisation

“
Methane-slip excuses collapse under real engine data
”

1. Introduction

The maritime propulsion landscape is undergoing its most profound transformation since the transition from steam to diesel. This change is being driven not by propulsion efficiency alone, but by a convergence of regulatory,

economic and societal pressures. International Maritime Organization regulations, regional frameworks such as the EU Emissions Trading System and FuelEU Maritime, tightening Carbon Intensity Indicator requirements and increasing scrutiny from charterers and financiers have collectively forced shipowners to reassess long-term propulsion strategies.

Liquefied natural gas has emerged as the dominant transitional fuel, not because it represents a final decarbonisation endpoint, but because it enables immediate compliance with sulphur and particulate-matter regulations while offering meaningful reductions in nitrogen oxides and carbon dioxide compared to heavy fuel oil. Within this LNG-fuelled ecosystem, two fundamentally different engine philosophies have evolved: high-pressure diesel-cycle engines and low-pressure Otto-cycle engines.

Part 1 of this technical series examined high-pressure diesel-cycle engines, particularly the ME-GI family, highlighting their advantages in efficiency and minimal methane slip but also their higher capital cost and system complexity. Part 2 completes the technical picture by focusing on low-pressure Otto-cycle engines—specifically MAN Energy Solutions' ME-GA and WinGD's X-DF platforms—which dominate cost-sensitive deep-sea segments such as container ships, bulk carriers, tankers and vehicle carriers.

Historically, low-pressure engines were regarded as a compromise solution: cheaper and simpler but

penalised by higher methane slip and slightly lower efficiency. Technological developments introduced between 2024 and 2025—most notably Variable Compression Ratio and advanced exhaust-gas recirculation—have fundamentally altered this assessment. This article provides a detailed engineering, operational and economic evaluation of these developments, drawing on validated shop-test data and early commercial experience

2. Fundamentals of Low-Pressure Otto-Cycle Combustion

Low-pressure dual-fuel engines admit gaseous fuel into the scavenge air at pressures typically between 5 and 16 bar, forming a homogeneous, lean premixed charge. The overall equivalence ratio commonly lies between 1.8 and 2.2, placing the mixture close to the lean flammability limit. This combustion concept is fundamentally different from diesel-cycle combustion, where fuel is injected directly into compressed air near top dead centre and combustion occurs in a locally rich, stratified environment.

2.1 Ignition Challenges in Lean Premixed Combustion

In a lean premixed environment, a conventional diesel injector is incapable of reliably igniting the charge. Spraying diesel fuel into such a mixture produces weak ignition kernels that struggle to propagate a flame front across the entire combustion chamber. Early low-pressure engines suffered from misfiring, high cycle-to-cycle variability and extensive methane slip due to incomplete combustion and quenching in crevice volumes.

To overcome these challenges, modern low-pressure engines employ specialised pilot-fuel injection systems that incorporate pressure-boosting or pre-chamber concepts. These systems generate multiple high-energy ignition jets that act as distributed ignition sources, initiating rapid flame propagation and stabilising combustion across the full load range.

2.2 Abnormal Combustion Phenomena

While premixed combustion offers advantages in NO_x control, it also increases sensitivity to abnormal combustion phenomena. Pre-ignition can occur if hot spots, glowing deposits, or excessive compression temperatures ignite the mixture before pilot injection. Knock arises when the unburned end-gas auto-ignites ahead of the flame front, producing violent pressure-rise rates capable of damaging pistons, bearings and cylinder heads.

These risks increase at high loads, elevated component temperatures, or when operating on LNG with a low methane number. Effective mitigation therefore requires sophisticated combustion monitoring, rapid control intervention and increasingly,



“
*Regulators misjudged
low-pressure engines' true
potential*
”

adaptive control of compression ratio and exhaust-gas composition.

3. MAN Energy Solutions ME-GA Technology

3.1 System Architecture

The ME-GA engine represents MAN Energy Solutions' low-pressure Otto-cycle dual-fuel platform. Gas is supplied through a Low-Flashpoint Fuel Supply System operating at 5.5–12 bar, marginally above scavenge-air pressure to ensure positive admission. Compared with high-pressure systems, the ME-GA fuel-gas supply arrangement is mechanically simpler, lighter and less energy-intensive.

Key components include low-pressure compressors or pumps, vaporizers, heat exchangers, filtration units and a Gas Valve Unit incorporating double block-and-bleed isolation. A Gas Regulating Unit dynamically adjusts supply pressure based on engine load, ensuring stable gas admission under all operating conditions.

3.2 Safety Gas Admission Valve Philosophy

At the core of ME-GA technology is the Safety Gas Admission Valve, which integrates a window valve and a gas-admission valve into a single safety-critical assembly. The electronically controlled window valve defines the crank-angle window during which gas

“

*Otto-cycle engines
outperform expectations—and
political narratives*

”

admission is permitted and remains spring-closed under all fault conditions. Only when the window valve is fully open can hydraulic pressure reach the gas-admission valve actuator.

This architecture provides a robust double-barrier safety concept. Untimely gas admission is physically impossible and any hydraulic or electronic failure results in immediate valve closure. The design philosophy reflects a fundamental requirement of premixed combustion systems: gas must never be admitted unless ignition conditions are fully controlled.

3.3 Pilot Fuel Injection and Sealing Systems

Ignition in ME-GA engines is provided by the Micro Booster Injection Valve. Pilot fuel is supplied at relatively low pressure and hydraulically amplified within the injector body to approximately 600 bar. The resulting ignition jets act as distributed high-energy



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sources capable of igniting the ultra-lean gas-air mixture reliably.

A dedicated sealing-oil system maintains strict pressure differentials between gas, fuel and hydraulic oil circuits, preventing cross-contamination. Continuous monitoring of sealing-oil pressure provides an additional safety layer, with automatic gas-mode shutdown triggered if differential limits are violated.

3.4 Combustion Control and Methane Slip

The Fuel Ratio Control system continuously adjusts air-fuel ratio, pilot-fuel quantity and injection timing based on load and cylinder-pressure feedback. Baseline methane slip for ME-GA engines typically ranges from 1.2 to 2.5 percent of gas consumed. When equipped with Exhaust Gas Recirculation, recirculating twenty to forty percent of exhaust gas, combustion temperatures are reduced, quenching distances shrink and oxidation of unburned methane improves, yielding slip reductions of up to thirty percent while maintaining IMO Tier III NO_x compliance.

4. WinGD X-DF and Variable Compression Ratio Technology

4.1 Conceptual Breakthrough

WinGD's X-DF platform applies the same low-pressure Otto-cycle principle but introduces a transformative feature: Variable Compression Ratio. Rather than operating with a fixed compromise compression ratio suitable for both diesel and gas modes, the VCR system enables real-time optimisation of compression ratio according to fuel type, load, ambient conditions, exhaust-gas recirculation rate and methane number.

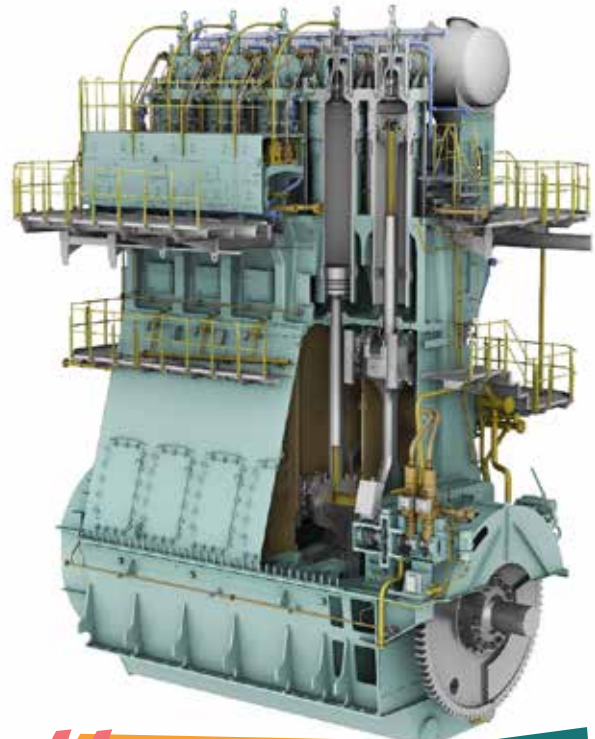
4.2 Mechanical Integration

The VCR system is integrated into the crosshead pin of the two-stroke engine. A hydraulically pressurised chamber alters the effective top dead centre position of the piston by several millimetres. By adjusting lubricating-oil pressure between approximately 40 and 50 bar, the system dynamically varies compression ratio between roughly 12:1 and 15:1.

The system uses standard lubricating oil, passive safety features and simple hydraulic components, contributing to high reliability and minimal maintenance requirements.

4.3 Operating Principle

In diesel mode, the engine operates at a high compression ratio to maximise thermal efficiency, approaching the performance of dedicated diesel engines. In gas mode, compression ratio is optimised to balance efficiency against knock resistance and methane slip. The control system continuously adapts



*Technology moved
faster than maritime climate
policy*

to variations in methane number, intake-air temperature and exhaust-gas recirculation.

Cylinder-specific adjustment capability allows fine balancing and compensation for wear or abnormal combustion behaviour, further enhancing operational robustness.

4.4 Performance Achievements

Extensive shop tests conducted in 2025 demonstrated a reduction in methane slip from approximately 1.19 percent to 0.83 percent of gas consumed, representing a thirty percent reduction. Fuel consumption improved by up to 5.8 percent in gas mode and 6.9 percent in diesel mode. These improvements result from optimised combustion phasing, reduced quenching distances and enhanced oxidation of gas trapped in crevice volumes.

From a regulatory perspective, methane-slip values below one percent fall well below the default factors used in EU ETS and FuelEU Maritime calculations, significantly reducing carbon-pricing exposure.

4.5 Integration with iCER

The Intelligent Control by Exhaust Recycling system complements VCR by moderating combustion



“Engine designers solved problems regulators kept debating”

temperatures and suppressing nitrogen-oxide formation. The engine control system coordinates exhaust-gas recirculation rate and compression-ratio adjustment, enabling Tier III compliance in gas mode without aftertreatment and providing an additional reduction in methane slip.

5. Emissions and Environmental Performance

All LNG-fuelled dual-fuel engines deliver near-zero sulphur-oxide and particulate-matter emissions due to the absence of sulphur in natural gas. Nitrogen-oxide emissions in gas mode are inherently low and meet Tier III limits without SCR in both ME-GA and X-DF engines.

Methane slip remains the critical environmental differentiator. High-pressure ME-GI engines achieve the lowest absolute slip due to diesel-cycle combustion. However, Variable Compression Ratio technology has dramatically narrowed this gap for low-pressure engines, reducing slip to approximately half the regulatory default value and delivering additional greenhouse-gas reductions when expressed as CO₂-equivalent.

6. Operational Flexibility and Reliability

Low-pressure engines offer seamless fuel switching, wide load-range capability and immediate reversion to liquid fuel. Variable Compression Ratio further improves part-load efficiency, manoeuvring stability and shaft-generator operability. Maintenance requirements align with standard dry-docking intervals and early fleet experience indicates high reliability with minimal additional maintenance burden.

7. Economic Assessment

Fuel savings dominate operational economics. Variable Compression Ratio delivers annual savings ranging from approximately US\$0.4 million for large bulk carriers to over US\$2 million for container ships. Payback periods typically range from one to fourteen

months. When avoided methane penalties under EU ETS and improved Carbon Intensity Indicator ratings are included, total annual economic benefit can exceed US\$5 million for large vessels.

8. Way Forward: 2026–2035

In the near term, optimisation of existing low-pressure fleets through EGR, iCER and VCR upgrades will be essential for compliance with FuelEU Maritime targets. In the medium term, ammonia-ready and hydrogen-capable engines will leverage VCR for combustion control. In the long term, hybrid propulsion systems combining dual-fuel engines, batteries and waste-heat recovery will push overall plant efficiency beyond sixty percent.

9. Conclusion

Low-pressure Otto-cycle dual-fuel engines have reached full technical maturity. MAN ME-GA provides the lowest-capital-cost solution with robust safety architecture, while WinGD X-DF with Variable Compression Ratio represents a step-change in efficiency, emissions performance and regulatory resilience. For most deep-sea vessels, low-pressure engines equipped with VCR now offer the optimum technical-economic solution and the clearest pathway toward carbon-neutral fuels.

List of Abbreviations

- BOG – Boil-Off Gas
- EGR – Exhaust Gas Recirculation
- iCER – Intelligent Control by Exhaust Recycling
- FRC – Fuel Ratio Control
- GVU – Gas Valve Unit
- LFSS – Low-Flashpoint Fuel Supply System
- MBIV – Micro Booster Injection Valve
- SGAV – Safety Gas Admission Valve
- VCR – Variable Compression Ratio

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Gas Trials of LNG Carriers

- CRYOGENIC VERIFICATION, FGSS PERFORMANCE, SAFETY LOGIC AND DUAL-FUEL ENGINE OPERATION - Part 2



Dhivakar Duraikkannu

ABSTRACT / SUMMARY

Gas trials are the most demanding and safety-critical stage in LNG carrier commissioning. This paper presents a detailed and technically enriched description of LNG gas trials, including inerting, Gassing up, tank cooldown, LNG loading, cryogenic system behaviour, BOG compression, A-PRS reliquefaction, FGSS performance, compressor sequencing, dual-fuel engine gas operation, ESD logic, methane-slip controls, gas detection validation, ventilation integration, and post-trial tank warm-up and aeration.

All additional “advanced technical checks” (tank pressure control logic, compressor surge conditions, methane slip reduction verification, thermal contraction behaviour, CCS stress monitoring, failover logic, low/high BOG scenarios, etc.) have been fully integrated into the appropriate sections.

KEYWORDS: Gas Trials, LNG Carrier, FGSS, BOG Compressors, A-PRS, JT Valves, Cargo Cooldown, LNG Loading, Safety Shutdown Logic, iCER, Methane Slip Control, GVU, Gas Commissioning, FGC, BBC, GCU, Cryogenic Line Contraction, CCS Stress Monitoring.

INTRODUCTION

Gas trials represent the first real LNG-handling operation for a newly

built LNG carrier. Unlike sea trials, which focus on hydrodynamics and propulsion, gas trials require the controlled introduction of cryogenic LNG at -160°C , verification of tank integrity, validation of cargo handling and boil-off gas management systems, and demonstration of stable gas-burning propulsion (X-DF, ME-GI).

These trials verify dozens of interlinked systems including CCS, CHS, FGSS, pumps, compressors, vaporizers, reliquefaction plants, GCU, forced vaporisation trains, safety interlocks, ventilation systems, ESD logic, tank pressure control, methane slip compliance, dual-fuel engine tuning, and automated redundancy.

More than 100 personnel—Class surveyors, shipyard engineers, containment designers, FGSS OEMs, engine specialists, cargo system vendors, automation teams, terminal representatives, and shipowner staff—participate in the multi-day trial program.

This enhanced article integrates 13 new advanced validation points (safety logic testing, CCS stress monitoring, methane slip tuning, line contraction checks, high/low BOG scenarios, failover logic, etc.) inside the respective trial procedures.

“Gas trials expose design flaws no simulator reveals”

1. PRE-GAS TRIAL PREPARATION

1.1 Inerting Cargo Tanks — Displacement Method

Before any LNG is loaded, cargo tanks must be inerted and moisture-free.

Nitrogen is introduced from the bottom, displacing air upwards to vent mast outlets.

Acceptance Limits:

- O₂ < 2% by volume
- Dew point < -40°C
- No pockets of air detected
- Cargo line purging fully completed

Integrated Advanced Point — Gas Detection Accuracy in Cryogenic Zones

Before LNG loading, fixed and portable methane detectors are validated for:

- response time
- accuracy under low temperatures
- cross-sensitivity with nitrogen
- alarm redundancy (dual-loop)

This is essential because gas sensors behave differently near cryogenic boundaries.

2. LNG LOADING AT TERMINAL

2.1 Pre-Loading Meeting

Terminal, shipyard, Class, and ship staff confirm:

- LNG rate & vapour return
- Cargo arm purging
- ESD-1 and ESD-2 logic verification
- Ventilation readiness
- Firefighting readiness
- Communication protocols

Integrated Advanced Point — Sequential Safety Logic Testing (IGC Code)

ESD logic is tested as follows:

- ESD-1 triggers: Close ESD valves → stop pumps → stop compressors → shut GVUs.
- ESD-2 triggers: Controlled physical disconnection of the LNG Transfer system between ship-shore.

This confirms that no gas path remains open during emergency shutdowns.

2.2 LNG Loading Arms & Cargo Line Preparation

200-mesh strainers protect against hydrates/debris. Water curtain, dry powder system, and deck spray remain active.

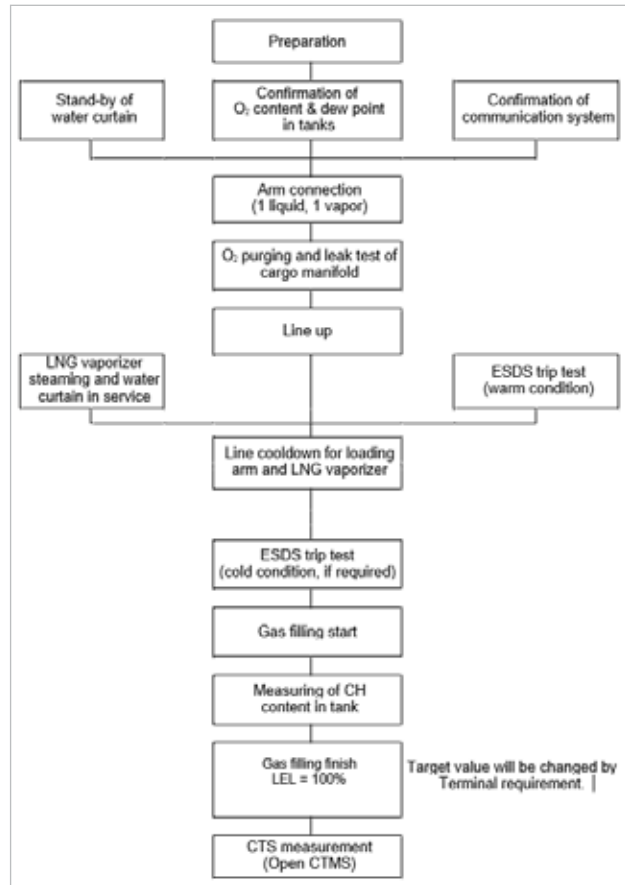
Advanced Point — Ventilation & Purging Efficiency

Ventilation inside compressor rooms and ducts are validated for:

- minimum ACH (air changes per hour)
- pressure balance with air locks
- purge cycle time after shutdown
- fan-failure interlocks

3. GAS FILLING & LINE COOLDOWN

Before allowing liquid LNG into tank No 4, gassing up to be done to displace nitrogen from LNG Tanks.



Cargo Tank & Cargo Line Cooldown Flowchart

Criteria:

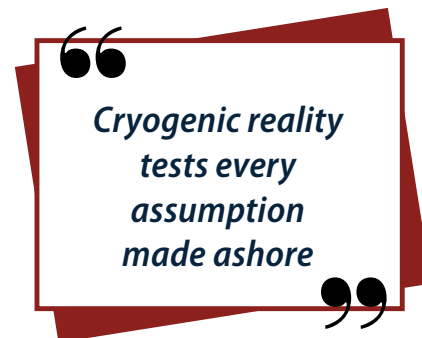
- Inlet temperature ≤ -100°C
- Vaporizer outlet ≤ 80°C
- CH₄ concentration ≥ 99% (TOP/MID/BOT)

Integrated Advanced Point — Thermal Contraction & Expansion Testing

Cryogenic lines undergo thermal contraction of several millimetres per meter of pipe.

During cooldown, engineers verify:

- bellow movement
- pipe stress data vs. design



- flange tightness
- insulation integrity

This prevents pipe cracking or flange leakage at -160°C.

4. LOADING OF LNG HEEL

Once lines cool down, LNG heel is loaded into Tank 4.

Critical checks:

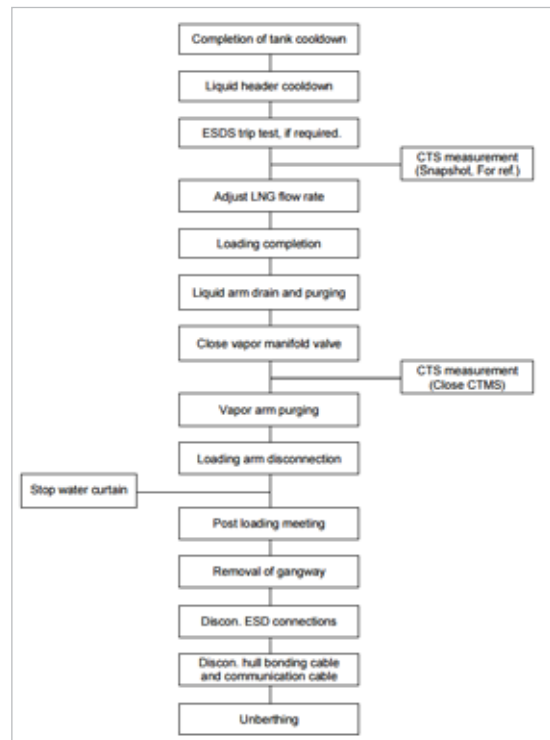
- Tank contraction monitoring
- Secondary barrier temperature gradient
- Pressure rise vs. BOG rate
- CTMS Integrity

Integrated Advanced Point – CCS Membrane Stress Monitoring

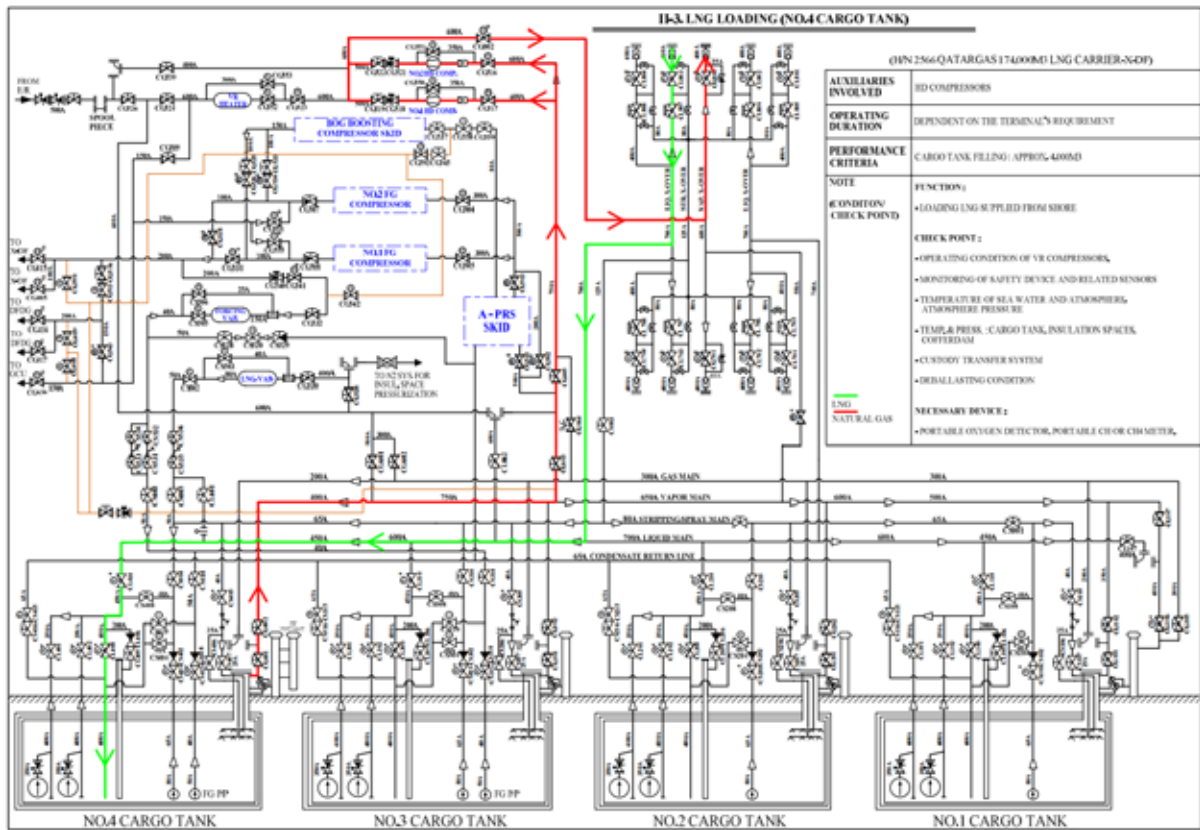
Class inspects:

- deformation sensors (MEMS) if fitted
- localised cold spots
- temperature differential across membranes
- NO96 / Mark III secondary barrier temperatures

Early detection avoids stress-induced membrane wrinkling.



Loading Flowchart



Loading Sequence

5. GAS FILLING & COOLDOWN OF TANKS 1, 2 & 3

Heel LNG from Tank 4 is used to gradually cool the remaining tanks.

Advanced Point – Hull Flexibility & Sloshing Evaluation

During at-gas trial conditions, engineers monitor:

- tank pressure fluctuations due to rolling
- sloshing loads
- temperature sensor stagger
- gauge damping behaviour
- CTMS Integrity

6. CRYOGENIC PUMP TESTING

Cryogenic pumps (cargo pp, Emergency cargo pp, stripping pp, fuel gas pp) are tested for:

- Flow rate
- Vibration signature
- Pump NPSH stability
- Motor temperature rise
- Discharge pressure fluctuation during ship motion
- Emergency Cargo Pump Operational check

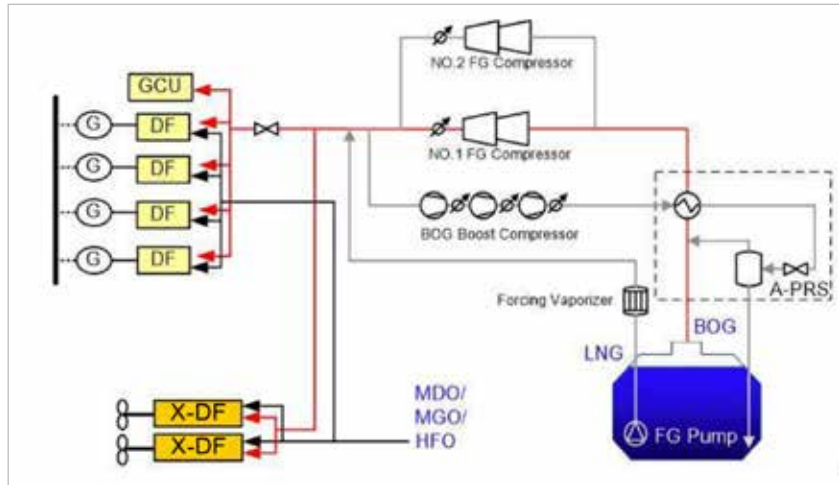
A notable part: verifying pump performance during ship motion.



Automation confidence collapses during real gas introduction

7. FUEL GAS SUPPLY SYSTEM (FGSS) TESTING

FGSS is the core of gas propulsion.

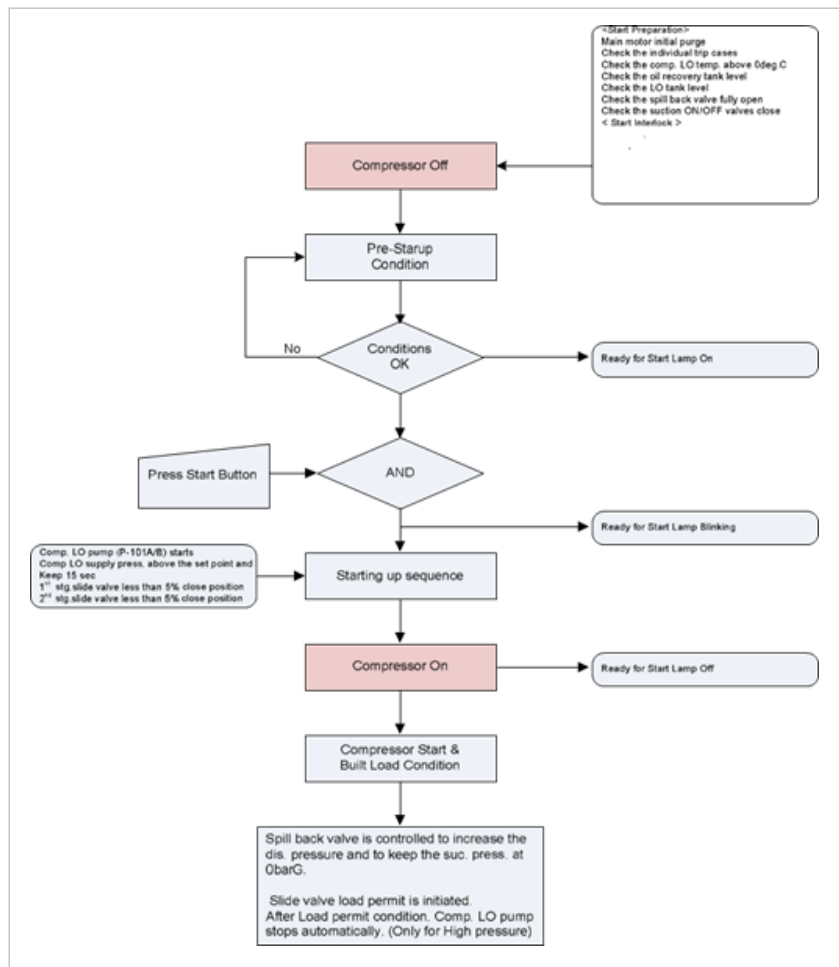


FGSS Layout

7.1 Fuel Gas Compressors (FGC)

FGC delivers:

- 13 barA gas → X-DF engines
- 6.5 barA gas → DFGEs



FG Compressor Starting Sequence

Integrated Advanced Points:

A. Tank Pressure Control Logic Validation

Tank pressure PID loop is tested for:

- load response
- stability
- avoidance of pressure hunting
- switching between:
 - o Mode A (FGC priority)
 - o Mode B (A-PRS priority)
 - o Mode C (GCU priority)

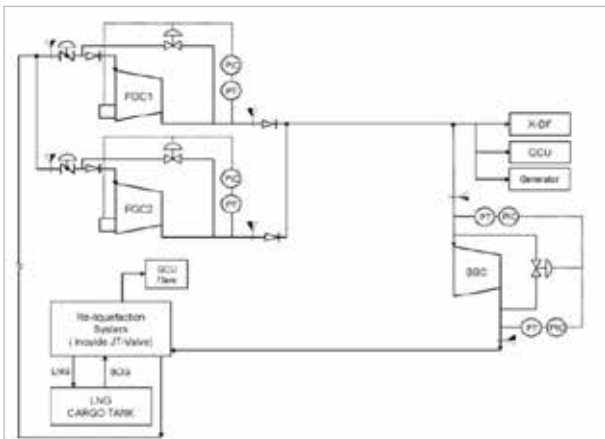
B. FGSS Failover Logic Test

Simulated failures include:

- loss of FGC #1 → auto-shift to #2
- loss of HP delivery → system fallback to LP mode
- GUV closure upon over/under pressure
- Gas trip sequence & changing over to DO mode

8. BOG BOOSTING COMPRESSOR (BBC)

BBC compresses BOG from 13 barA → 151 barA.



Compressor Layout

Integrated Advanced Points:

- High BOG Scenario - BOG artificially increased by warming lines; A-PRS + GCU must stabilize tank pressure.
- Low BOG Scenario - Forced reliquefaction creates insufficient BOG; FGC must maintain steady engine supply.
- Compressor Surge Margin Tests - Evaluates stability under fluctuating suction conditions.

9. FORCING VAPORIZER TESTS

Forcing vaporizers ensure stable BOG supply to engines.

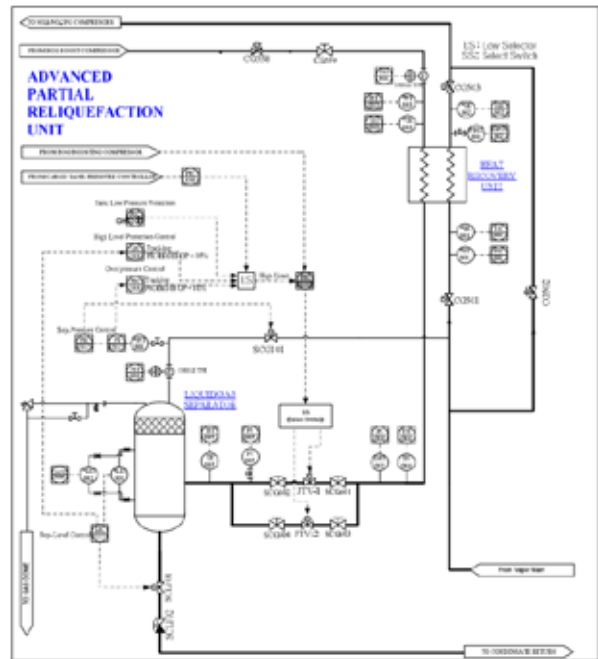
Advanced validation includes:

- thermal shock protection
- parallel run with FGC
- over-temperature alarms
- safety interlock correctness

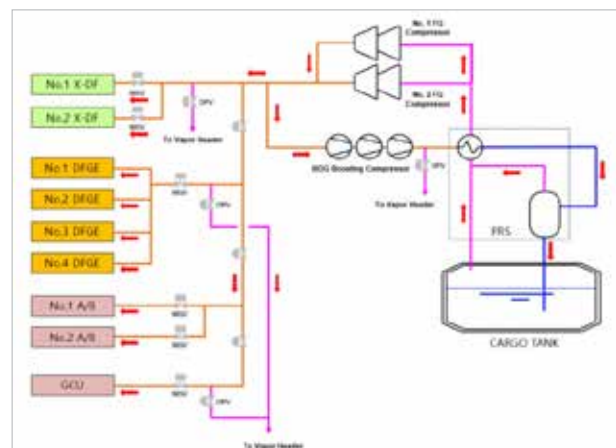
10. A-PRS (ADVANCED PARTIAL RELIQUEFACTION SYSTEM)

Integrated tests:

- Heat Recovery Unit thermal performance
- Leak detection in vapour lines
- Stop/start sequencing
- Tank pressure control hierarchy
- JT Valves efficiency



Advanced Partial Reliquefaction Unit



FGSS & PRS System Overview

11. GAS COMBUSTION UNIT (GCU)

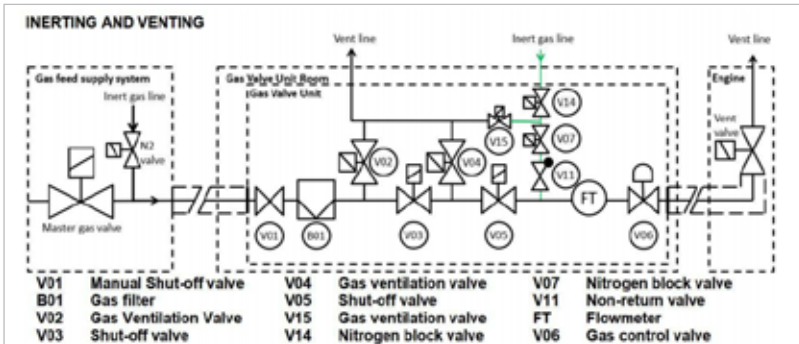
Enhanced tests include:

- GCU Capacity Test
- Purge gas volume validation
- Flame stability at 10-15% load
- Rapid-venting simulation
- Safety trips and burner logic

12. AUXILIARY ENGINE GAS COMMISSIONING

Advanced enhancements:

- High-Gas Load Stability
- ESD-Induced Gas Trip
- Tuning Against Methane Number (Mn) Variation
- Blackout recovery in diesel mode & gas mode operation



13. MAIN ENGINE GAS COMMISSIONING (X-DF / ME-GI)

Integrated Advanced Points:

A. Methane Slip Reduction Verification

For X-DF engines with iCER and ME-GI engines with EGR:

- Methane slip measurement
- EGR stability checks
- iCER performance check
- Scavenge optimisation
- Cylinder pressure balancing
- Fuel changeover stability
- CSM/FSM Mode operation.

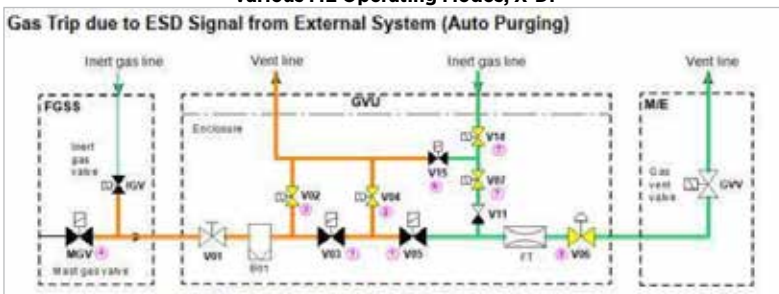


B. Low-Load Gas Mode Validation

Minimum gas load operation.



Various ME Operating Modes, X-DF



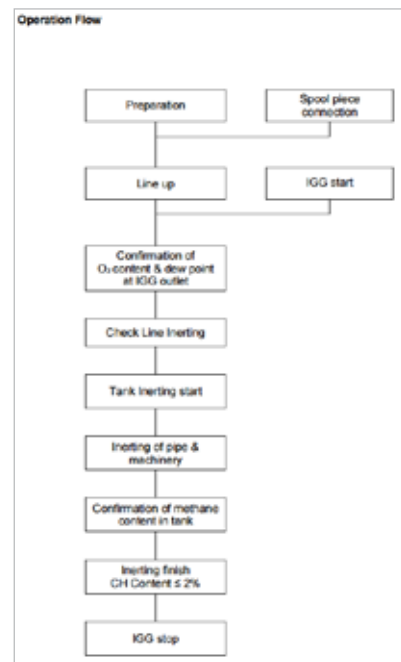
ME GVU & Venting Drawing

14. UNLOADING OF LNG HEEL



Unloading Flowchart

15. WARM-UP, INERTING & AERATION



Inerting Flowchart

Integrated Advanced Points:

- IGG performance under various flow rate & load
 - O2 & Dew point checks.
 - IG Line NR flap checks.
 - O2 Analyser performance.
- Aeration carried out after Inerting.

FINAL SUMMARY

The updated Gas Trials article now includes:



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- Compressor surge margin
- Methane slip reduction verification
- FGSS failover logic

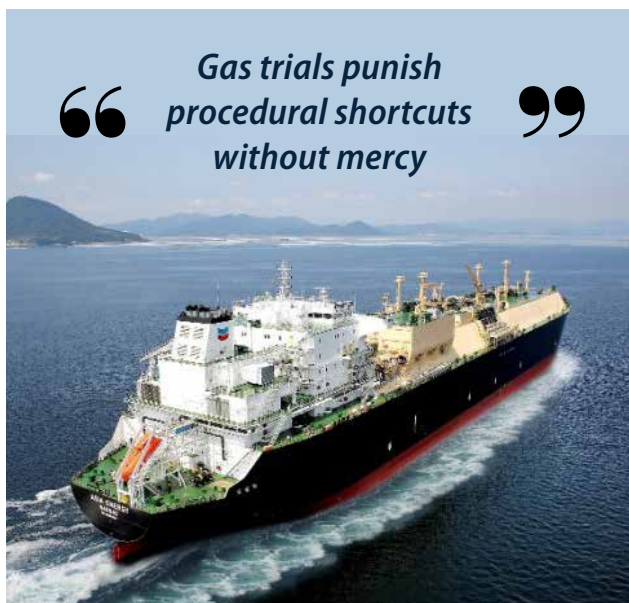
- Ventilation/purging efficiency
- Membrane stress checks
- Gas detection & Gas Sampling system accuracy
- Human-machine interface quality
- Endurance performance of A-PRS, FGC, BBC.

Acknowledgements

I would like to thank MMS – Technical, Operations & Manning Departments for giving me an opportunity to attend LNG Vessel Sea & Gas Trials.

References:

1. SIGTTO Guidance for Gas Trials on LNG Carriers
2. LGHP SIGTTO
3. LNG Vessel Cargo Operating Manual
4. SEA & GAS Trail procedures.



About the Author



Dhivakar Duraikkannu, currently serving as Chief Engineer on LNG carriers with MMSI, with prior experience as Gas Fleet Technical Superintendent, Singapore. Visiting Faculty at the Hindustan Institute of Maritime Training (HIMT), Chennai. Holds a B.S. in Marine Engineering and an MBA in Shipping & Port Management; Fellow of IME(I). Specialises in cryogenic containment, FGSS, BOG management and LNG dual-fuel machinery operations.

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Rust Beneath the Waves



Naveen S. Singhal
M. M. Saggi

Keywords: Maritime safety; machinery failure; ISM Code; crew fatigue; ship maintenance; Indian coastline; maritime regulation; shipping governance; environmental risk; seafarer welfare

While the world's shipping fleet looks bigger than ever, its safety culture is quietly rotting and India has the most to lose.....

Abstract

Despite unprecedented growth in global maritime trade, shipping safety is deteriorating beneath the surface. Machinery failures now dominate casualty statistics, driven by near-continuous vessel operation, compressed port stays, deferred maintenance, and chronic crew fatigue. The International Safety Management (ISM) Code, intended as the backbone of maritime safety governance, has failed to keep pace with these operational realities, allowing responsibility to diffuse between owners, managers, and crews. Using recent incidents affecting Indian waters as context, this article argues that the erosion of maintenance discipline and human endurance represents a systemic risk rather than a series of isolated technical failures. It concludes that India, given its strategic maritime exposure and role within the International Maritime Organization, has both the incentive and the standing to push for meaningful reform before further environmental, economic, and human costs are incurred.

“
Machinery failures expose hollow efficiency-driven shipping model”

Introduction

Global shipping has expanded relentlessly in scale, speed, and complexity, yet its safety foundations have not evolved at the same pace. While vessels grow larger and schedules tighter, the systems meant to ensure seaworthiness—maintenance regimes, crew welfare frameworks, and regulatory accountability—are being stretched to their limits. The result is an industry that appears operationally efficient on paper but is increasingly brittle in practice.

For India, the consequences of this imbalance are immediate and severe. As a major supplier of seafarers, a rapidly expanding port state, and a nation with an extensive and environmentally sensitive coastline, India bears disproportionate exposure to failures originating far beyond its territorial waters. Recent groundings, sinkings, machinery breakdowns, and pollution incidents around the subcontinent are not isolated mishaps; they are symptoms of a deeper structural decay in how global shipping is operated and governed. This article examines that decay, focusing on machinery reliability, human fatigue, and regulatory blind spots—particularly within the International Safety Management framework—and argues that without systemic reform, the risks facing India will only intensify.

“
**ISM Code masks responsibility
while ships quietly decay**”

Cases in India and the subcontinent:

- In 2025 the container ship *MSC Elsa-3* sank off Kerala.
- In 2025 *Wan Hai 503* spilled oil and chemicals into the Arabian Sea, again near Kerala’s fragile coast.
- In 2022 the tanker *MT Parth* released oil and bitumen off Maharashtra.
- Earlier disasters still haunt regulators:
 - o *MV Rak Carrier* went down off Mumbai in 2011,
 - o *MSC Chitra* collided with another ship in Mumbai harbour in 2010,
 - o *MV Black Rose* sank near Paradip in 2009.
 - o *Dawn Kanchipuram* collision with outbound LPG tanker *MT BW Maple* at Ennore near Chennai in the year 2017 leading to bunker oil leak from the ship
- Even accidents outside Indian waters do not stay there.
 - o When the container ship *X-Press Pearl* caught fire and sank off Sri Lanka in 2021, plastic pellets and chemicals washed up along India’s southern beaches.

Machinery Failure

Marine insurers and casualty investigators are blunt about what is going wrong. Machinery failure now accounts for over 40 percent of serious shipping incidents worldwide - more than collisions, groundings or navigational mistakes. Lloyd’s List puts the figure at 43 percent.

The cause is as prosaic as it is alarming: ships are not being allowed to stop. In the 20th century, most merchant vessels periodically went into “lay-up” – i.e. the time alongside or at anchor when the engines were shut down and engineers could dismantle, inspect and overhaul critical machinery. Today, in the name of efficiency, that has become rare. Vessels are expected to move almost continuously, with maintenance squeezed into hurried port calls or improvised at anchor.

Chief engineers are pushed into a grim juggling act to keep the ship running, keep the paperwork clean and somehow keep the machinery alive. Some take risks, immobilising engines during port stays or at anchor to attempt essential repairs, often skirting port regulations and safety norms. Others tick the boxes without doing the work. Ships limp on until, one day, the small failures line up into a major disaster.

The International Safety Management (ISM) Code, the backbone of the global maritime safety regime,

was designed to prevent this. It requires companies to operate ships safely and maintain them properly. But it never anticipated an industry that would try to eliminate downtime altogether.

Human Cost

Modern shipping has become a paradox: faster, more automated and more exhausting. In the past, a ship might spend four to six days in port. Crews could step ashore, see daylight that was not filtered through a porthole, and mentally reset before the next leg. Today, container ships and bulk carriers are often turned around in 12 to 36 hours. Crews work through cargo operations, inspections and paperwork, and sail again without ever leaving the quay.

At the same time, contracts have not shortened. Six to ten months at sea remains common. Worse, many shipowners have cut crew numbers to save money, sometimes in defiance of international guidelines. The result is a small, overworked team running a complex industrial plant that never sleeps. Investigations link fatigue to poor decisions on the bridge and in the engine room, to rising mental-health problems including suicide. It is also quietly poisoning the future of the profession as fewer young people want to go to sea when it looks like a form of floating bonded labour.

Shipping has always been bureaucratic, but the paperwork explosion of recent decades has been particularly perverse. Crews are required to comply with thick binders of checklists and procedures irrelevant to the actual equipment on board. They allow ship-management companies to show flag-state regulators that they have a

“
**Paper compliance
replaces real
maintenance at sea**”

system, even if that system has little to do with the ship’s reality.

Everyone in the chain knows this, including the maritime administrations and the International Maritime Organisation (IMO) that oversees them. Yet the fiction persists.

Holes in the Code

The weaknesses are written into the rules. The ISM Code, adopted in the 1990s after a spate of high-profile accidents, was meant to force companies to take responsibility for safety. In practice it left some of the most powerful actors off the hook.

The most glaring omission is the shipowner. Under the code, operational responsibility is often delegated to a

ship-management company, sometimes for a modest fee. If something goes wrong, the owner can point to the manager; the manager can point to the crew. True accountability dissolves. Owners have lobbied hard to keep it that way.

The code also says nothing about mandatory lay-up periods for maintenance, even though modern ships are more complex and failure-prone than ever. It leaves crew-contract lengths frozen in a 20th-century world of slower shipping and longer port stays. It allows owners to pressure flag states into approving smaller crews. And it tolerates generic procedures that bear little relation to the hardware on board.

In November 2025 America's National Transportation Safety Board released its final report into the 2024 collision of the container ship *MV DALI* with the Francis Scott Key Bridge in Baltimore. The board highlighted structural flaws in the ISM Code itself and urged the United States to push the IMO to fix them. It was an unusually direct challenge to the global rulebook.

For India, this matters more than most. Its ports are busier every year. Its seafarers are on almost every major shipping line. Its coastal waters have already paid a high price for global negligence. And in November 2025 India was re-elected to the IMO Council in Category B - the group of ten countries with the greatest interest in international seaborne trade. That seat gives New Delhi a platform to shape the rules.

The country's own maritime regulator, the Directorate General of Shipping, has been urged by industry insiders to tighten standards for Indian-flagged vessels and to push for broader reform. But unilateral action is not enough. Ships are global creatures: they are owned in one country, managed in another, flagged in a third and crewed in a fourth. Only the IMO can change the incentives that drive them.

There is an opportunity for a coalition. The United States, prodded by its own investigators, has reasons to want a tougher ISM Code. Other trading nations that depend on clean, reliable sea lanes - from Japan to the EU - share the same interest. Together they could push for a rewrite that reflects how shipping actually works in the 21st century.

Such a rewrite would be practical. It would make shipowners explicitly responsible for safety, not just their agents. It would require planned maintenance periods that cannot be wished away by scheduling software. It would recognise that human beings cannot work safely for months on end without rest or relief. And it would replace paper compliance with procedures tied to real equipment.

Shipping is famously conservative. It changes only after disaster. India does not need to wait for that. Its

“
India pays
price for global
shipping's hidden
shortcuts

economic future is tied to the sea, as it has been for centuries. The rust beneath the waves is spreading. Whether it is scraped off or allowed to eat through the hull will depend, in no small part, on what happens in the rule-making rooms of the IMO.

Conclusion

The deterioration of shipping safety is not the result of a single bad regulation, negligent crew, or unlucky voyage.

It is the predictable outcome of an industry that has optimised speed, utilisation, and paperwork compliance while steadily eroding the physical and human margins that once absorbed risk. Continuous operation without genuine maintenance windows, reduced manning, prolonged contracts, and procedural formalism have combined to make modern ships more vulnerable, not more resilient.

For India, the stakes are particularly high. Its seafarers form the backbone of global shipping operations, its ports anchor critical trade corridors, and its coastal ecosystems are among the first to suffer when systemic failures surface at sea. Incremental enforcement or national-level tightening, while necessary, will not be sufficient in an industry whose ownership, management, flagging, and crewing are globally fragmented.

Meaningful improvement requires reform at the level where incentives are set—within international rule-making itself. Reasserting shipowner accountability, mandating realistic maintenance downtime, aligning crew-contract norms with operational intensity, and replacing generic paperwork with equipment-specific safety systems are no longer optional upgrades; they are structural necessities. Shipping's conservatism ensures that change often follows catastrophe. India's challenge—and opportunity—is to help force reform before the next failure writes its lessons in oil, steel, and human lives along its shores.

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Creating Value for Reliability-Centered Maintenance in Ship Machinery Using Big Data and Artificial Intelligence



Ullhas S. Kalghatgi

Abstract

Global shipping carries close to ninety percent of world trade by volume and remains the backbone of international commerce. At the same time, the industry is under unprecedented pressure to operate ships more safely, more efficiently and with lower environmental impact, often with reduced crew sizes and tighter operating schedules. Traditional maintenance approaches—largely based on fixed intervals, manual records and reactive interventions—are increasingly inadequate for this operating reality. Reliability-Centered Maintenance (RCM), though conceptually robust, has historically depended on manual data collection and expert judgment, limiting its effectiveness onboard modern, sensor-rich vessels.

This article examines how Big Data analytics, the Internet of Things (IoT) and Artificial Intelligence (AI) can transform RCM from a largely procedural framework into a dynamic, value-generating maintenance strategy for ship machinery. It explains the fundamentals of RCM, the nature of maritime Big Data and the role of AI-driven analytics in predicting failures, optimising maintenance windows and improving machinery availability. The paper further discusses communication

architectures, emerging technologies such as cloud and edge computing and the practical challenges associated with data quality, cybersecurity, bandwidth and human factors. The article concludes that the integration of Big Data and AI with RCM is no longer optional but essential for achieving sustainable, safe and economically viable ship operations in the digital era.

Keywords: Reliability-Centered Maintenance; Big Data; Artificial Intelligence; Internet of Things; Ship Machinery; Predictive Maintenance; Digital Transformation; Maritime Operations

1. Introduction

The maritime industry is often described as conservative, slow to adopt change and deeply rooted in established practices. For decades, this conservatism was justified by the harsh operating environment at sea, the long service lives of ships and the safety-critical nature of marine engineering systems. However, the operating context of shipping has changed dramatically. Ships today are larger, more complex and more technologically advanced than ever before. At the same time, they operate with fewer crew, shorter port stays and intense commercial pressure to minimise downtime.

Machinery onboard modern ships—main engines, auxiliary engines, boilers, pumps, compressors and associated systems—forms a complex, interconnected industrial plant that must operate continuously and reliably. Failures in these systems can lead

“
Traditional maintenance fails in a data-rich shipping world”

RELIABILITY-CENTERED MAINTENANCE (RCM)



not only to off-hire and repair costs but also to serious safety incidents, environmental damage and reputational harm. In this environment, maintenance has become a strategic function rather than a purely technical one.

Reliability-Centered Maintenance was developed to address precisely this challenge: how to maintain complex systems in a way that preserves their intended functions, manages risk and optimises resources. Yet, in practice, shipboard RCM has often been reduced to compliance-driven maintenance plans and paperwork-heavy procedures. The emergence of digital technologies—sensors, connectivity, data analytics and artificial intelligence—offers an opportunity to reclaim the original promise of RCM and elevate it into a powerful decision-support and value-creation tool.

This article explores how Big Data and AI can be harnessed to enhance RCM in ship machinery maintenance, enabling a shift from time-based and reactive approaches to predictive, condition-based and risk-informed strategies.

2. Reliability-Centered Maintenance: Concept and Limitations

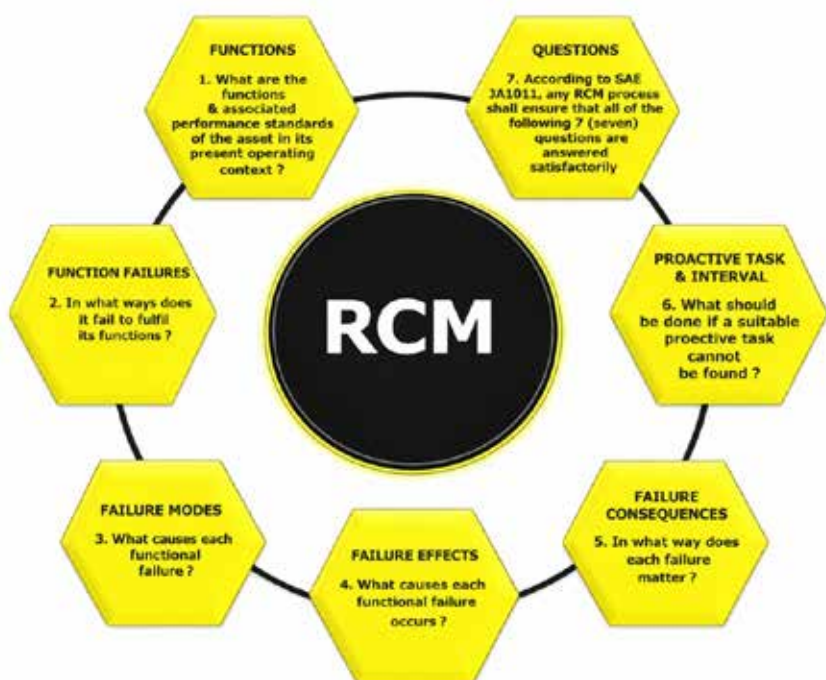
Reliability-Centered Maintenance originated in the aviation and nuclear industries during the late 1970s, where system failures carried unacceptable consequences. The central idea of RCM is deceptively simple: maintenance should focus on preserving system functions, not merely preventing failures. It asks fundamental questions such as what functions an asset performs, how it can fail, what causes those failures and what consequences arise when failures occur.

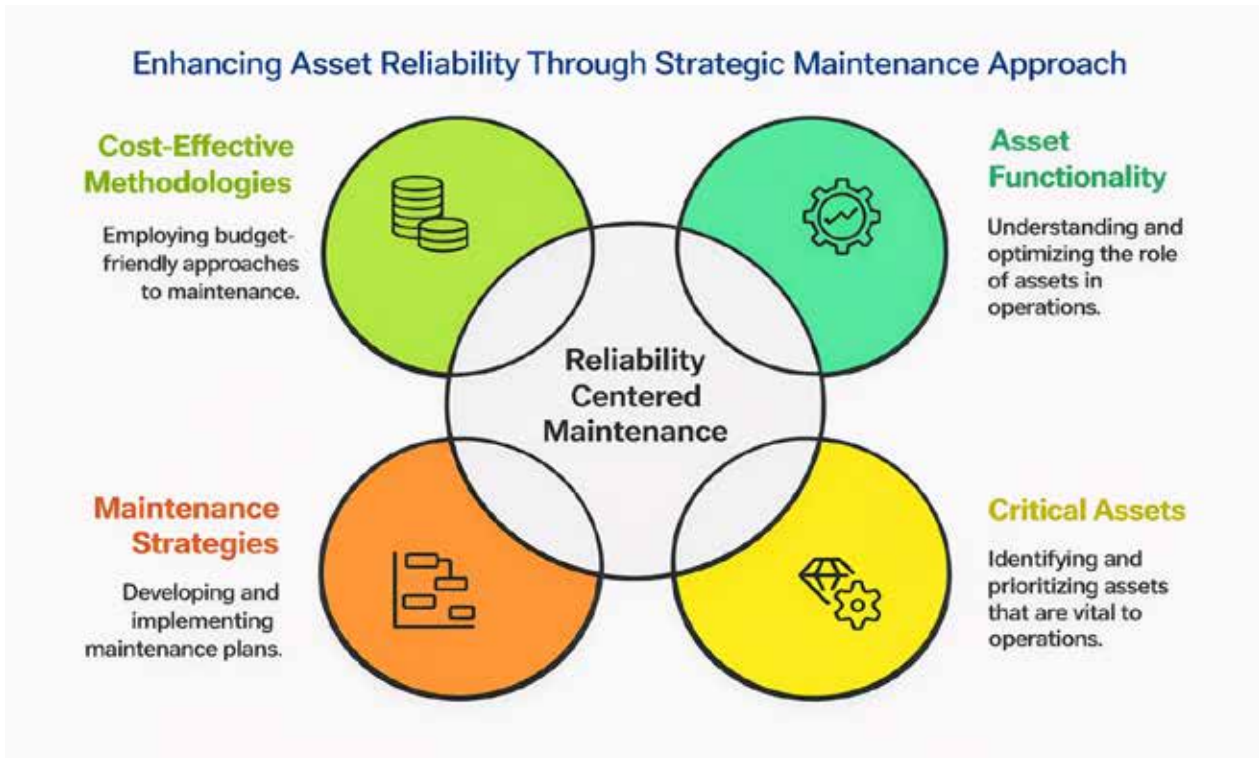
RCM distinguishes between different types of failures such as -

functional failures, potential failures and total failures—and emphasises the identification of failure modes and effects. Based on this analysis, appropriate maintenance tasks are selected, which may include condition monitoring, scheduled restoration, scheduled replacement, or in some cases, run-to-failure strategies.

In theory, RCM is ideally suited to ship machinery, where failure consequences range from minor inefficiencies to catastrophic events. In practice, however, several limitations have constrained its effectiveness onboard ships.

First, traditional RCM relies heavily on historical failure data, expert judgment and manual inspections. Onboard data collection has often been limited to periodic logbook entries, alarm records and subjective assessments by engineers. This results in sparse, low-resolution datasets that are insufficient for capturing early signs of degradation.





Second, maintenance schedules derived from RCM analyses are frequently implemented as static plans. Once approved, these plans may remain unchanged for years, even as operating conditions, fuel quality, crew competence and equipment age evolve.

Third, the increasing reduction in crew numbers and port turnaround times has reduced the practical opportunity to carry out thorough inspections and maintenance tasks. As a result, RCM risks becoming a paper exercise rather than a living maintenance philosophy.

These limitations do not invalidate RCM; instead, they highlight the need for better data, faster feedback loops and more intelligent analysis—precisely the areas where Big Data and AI can add transformative value.

3. Big Data in the Maritime Context

Big Data is often described using the so-called “four Vs”: volume, velocity, variety and veracity. In the maritime context, all four are increasingly evident.

Modern ships are equipped with thousands of sensors measuring pressures, temperatures, flows, vibrations, electrical loads, emissions and control signals. Automation systems, voyage data recorders, ECDIS, engine control units and performance monitoring platforms continuously generate data. The sheer volume of this data far exceeds what human operators can manually process.

Velocity refers to the speed at which data is generated and needs to be processed. Many machinery parameters change rapidly, especially during transients such as maneuvering, load changes, or abnormal conditions. Delayed analysis reduces the value of this data for operational decision-making.

Variety reflects the diversity of data types, including numerical sensor readings, alarm logs, maintenance records, images, vibration spectra and even unstructured text from reports. Integrating these heterogeneous data sources is a significant challenge.

Veracity addresses data quality and reliability. Sensors may drift, fail, or produce noisy signals. Data gaps may arise due to communication outages or human error. Without careful validation and cleansing, data-driven decisions can be misleading or dangerous.

Despite these challenges, Big Data represents a largely untapped asset for ship operators. When properly managed and analysed, it provides unprecedented visibility into machinery behavior, operating conditions and degradation patterns—exactly the insights required for effective RCM.





4. Artificial Intelligence and Advanced Analytics

Artificial Intelligence refers to a broad set of techniques that enable machines to perform tasks traditionally associated with human intelligence, such as learning, pattern recognition and decision-making. Within the maintenance domain, AI is most commonly applied through machine learning and deep learning algorithms.

Machine learning systems learn from historical data to identify relationships between inputs and outputs without being explicitly programmed. In ship machinery maintenance, this might involve learning how vibration signatures change as a bearing degrades or how exhaust temperatures evolve before a turbocharger failure.

Deep learning, using neural networks with multiple layers, is particularly effective at handling complex, high-dimensional datasets. It can detect subtle patterns that may be invisible to conventional statistical methods or human analysts.

Unlike traditional rule-based monitoring systems, AI-driven analytics can adapt as new data becomes available. This adaptability is critical in maritime operations, where machinery behavior varies with load, fuel type, ambient conditions and operational profile.

When integrated with RCM, AI enables the identification of potential failures well before functional failure occurs. This shifts maintenance from reactive or calendar-driven interventions to predictive actions based on actual equipment condition and risk.

5. Creating Value for RCM Through Big Data and AI

The true value of integrating Big Data and AI with RCM lies in transforming maintenance from a cost center into a strategic enabler of operational excellence.

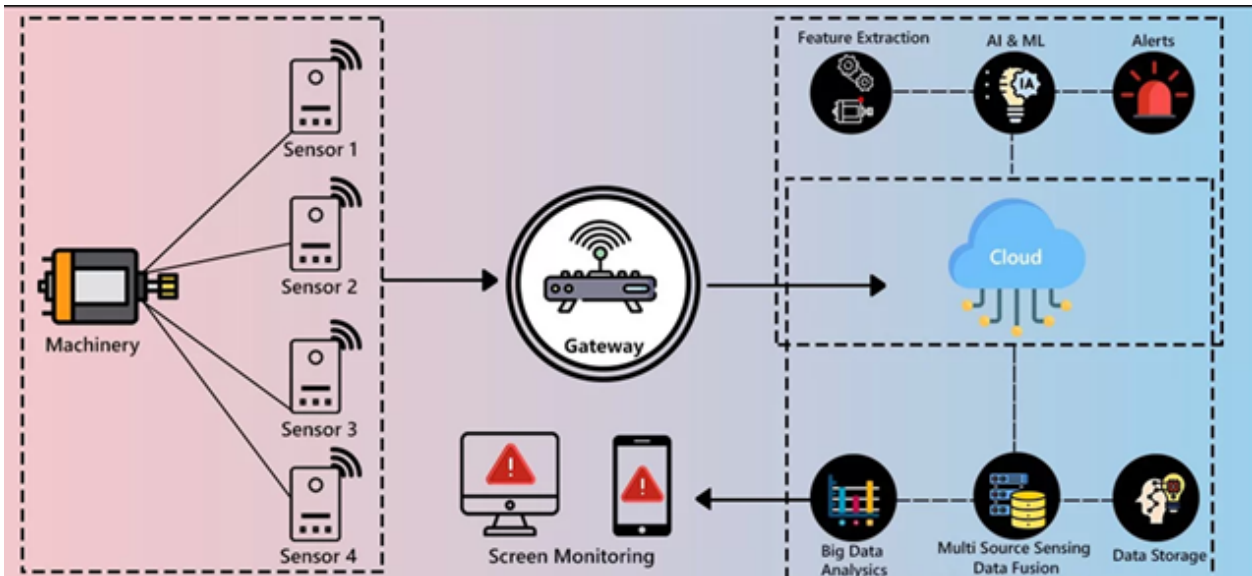
5.1 From Preventive to Predictive Maintenance

Traditional preventive maintenance is based on fixed intervals recommended by manufacturers or derived from

“Big data exposes inefficiencies crews quietly compensate”

historical experience. While simple to implement, this approach often results in unnecessary maintenance or, conversely, missed failures.

Predictive maintenance uses data-driven models to estimate the remaining useful life of components and identify early signs of degradation. For example, AI algorithms can correlate changes in lube oil properties, bearing temperatures and vibration spectra to predict impending failures. Maintenance can then be scheduled at the most opportune time, minimising disruption and cost.



5.2 Improved Risk Management

RCM emphasises understanding failure consequences. Big Data analytics enhances this by quantifying risk in near real time. By continuously assessing machinery condition and operating context, AI systems can highlight which assets pose the highest risk at any given moment. This allows engineers and managers to prioritise resources effectively.

5.3 Enhanced Machinery Availability

Unplanned downtime is among the most expensive outcomes of poor maintenance. Predictive insights enable planned interventions during port stays or low-demand periods, increasing overall machinery availability and vessel utilisation.

5.4 Knowledge Retention and Decision Support

As experienced engineers retire and crew turnover increases, valuable tacit knowledge is lost. AI systems

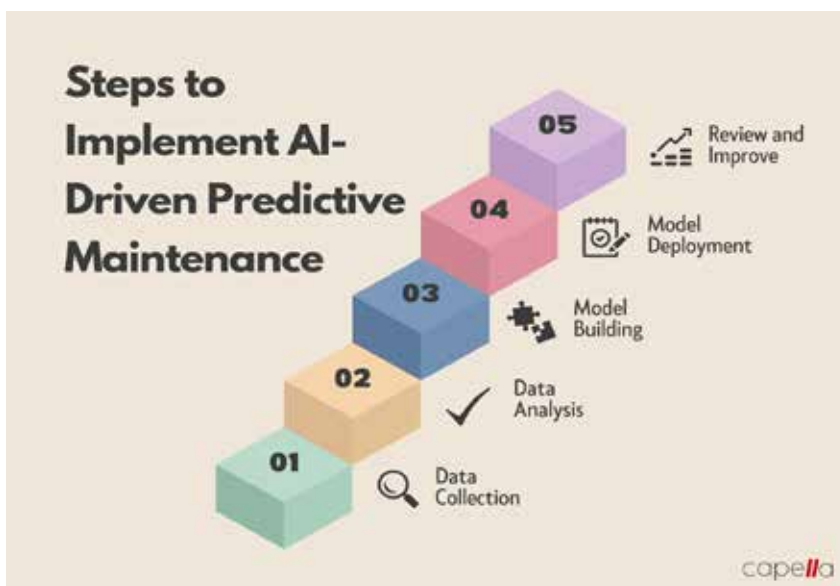
trained on historical data and expert input can capture and formalise this knowledge, providing decision support to less experienced personnel and improving consistency across fleets.

6. Communication Architecture: Ship to Shore Integration

Effective use of Big Data and AI requires reliable communication between shipboard systems and shore-based analysis platforms. Modern communication architectures typically combine onboard networks, satellite links and terrestrial infrastructure.

Shipboard systems collect and preprocess data from sensors and control systems. Selected datasets are transmitted to shore-based servers or cloud platforms, where more computationally intensive analytics are performed. Results and recommendations are then fed back to the vessel.

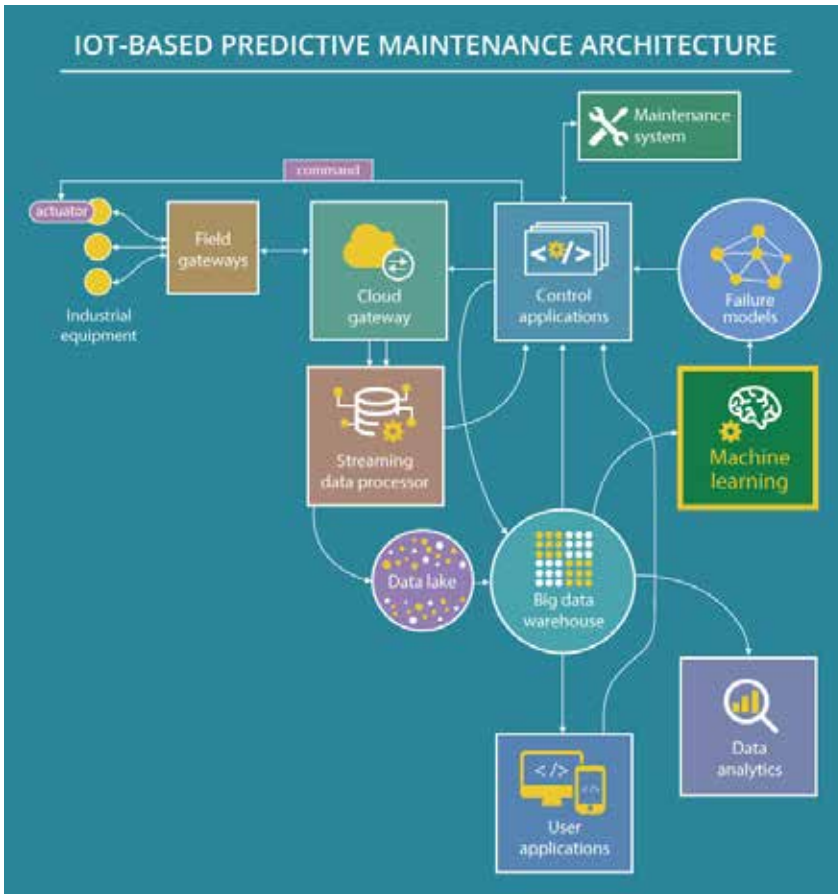
Given bandwidth constraints and cost considerations, not all data can be transmitted. Intelligent data selection and compression strategies are therefore essential. This is where edge computing plays a critical role.



7. Emerging Technologies: Cloud and Edge Computing

Cloud computing provides scalable storage and processing power, enabling fleet-wide analytics and benchmarking. It supports advanced AI models that would be impractical to run onboard.

Edge computing complements this by performing initial data processing close to the source. Onboard



must be demonstrated through reduced failures, lower maintenance costs and improved operational performance.

9. Future Outlook

The convergence of Big Data, AI, IoT and advanced communications is reshaping the maritime maintenance landscape. As regulatory pressure increases and operational margins tighten, data-driven RCM will become a competitive necessity rather than a technological novelty.

Future developments are likely to include tighter integration between maintenance systems, energy efficiency monitoring and emissions management. Autonomous and semi-autonomous vessels will further increase reliance on intelligent maintenance systems capable of operating with minimal human intervention.

10. Conclusion

Reliability-Centered Maintenance provides a sound conceptual framework for managing ship machinery, but its full potential can only be realised through the effective use of data and intelligence. Big Data and Artificial Intelligence offer the tools needed to transform RCM into a dynamic, predictive and value-generating strategy.

By enabling earlier detection of degradation, better risk prioritisation and smarter maintenance planning, digital technologies enhance safety, reduce costs and improve operational resilience. While challenges remain in data quality, cybersecurity and human acceptance, these are manageable with thoughtful design and strong leadership.

In an industry facing growing complexity and scrutiny, the integration of Big Data and AI with RCM represents not just a technological upgrade but a fundamental evolution in how ships are maintained and operated. Embracing this evolution is essential for the sustainable future of maritime transportation.

algorithms can filter noise, detect anomalies and trigger alerts without relying on continuous connectivity. Only high-value data or summarised insights are transmitted to the cloud.

The combination of cloud and edge computing enables a balanced architecture that maximises analytical capability while respecting practical constraints of maritime communication.

8. Constraints and Challenges

Despite its potential, the integration of Big Data and AI into RCM faces several challenges.

Data quality remains a fundamental issue. Poor sensor calibration, inconsistent data standards and incomplete datasets can undermine analytical accuracy.

Cybersecurity is another critical concern. Increased connectivity exposes ships to cyber risks that must be managed through robust security architecture and crew awareness.

Human factors also play a decisive role. Engineers and managers must trust data-driven recommendations and understand their limitations. Training and change management are therefore essential components of any digital maintenance initiative.

Finally, economic justification must be clear. While digital systems require upfront investment, their value

About the Author



Ulhas S. Kalghatgi is a former Indian Register of Shipping Chief Surveyor and Senior Vice President. He has decades of experience in ship surveys, machinery reliability, maintenance strategy and maritime regulation and writes on RCM, transformation, Big Data and AI.

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Boilers, Burners and Blowbacks: Accident Investigation Techniques for Marine Steam Systems

Marine Engineering Accident Investigation Series – Part III



Gajanan Karanjikar

Abstract

Marine steam systems are often taken for granted on modern bulk carriers and tankers. Auxiliary boilers run quietly in the background, feeding fuel to heating systems, cargo pumps and hotel services. When something goes wrong, however, the consequences can be sudden and severe: furnace explosions, blowbacks, tube ruptures, fires and long off-hire delays. This article outlines a practical investigation framework for boiler and burner incidents, focusing on combustion control faults, fuel quality, safety interlocks and post-incident reconstruction. Two representative case studies illustrate typical chains of failure and the associated legal and financial consequences for owners. The discussion is framed against relevant statutory and class requirements under SOLAS, the ISM Code and classification rules, to turn each boiler casualty into a structured source of learning rather than an isolated mishap.

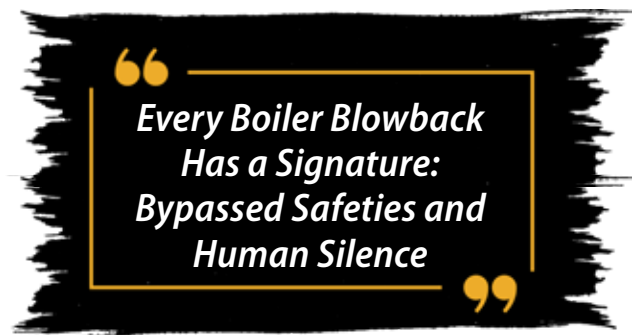
Keywords: marine boiler, burner blowback, combustion control, fuel quality, safety interlocks, ISM Code, SOLAS, accident investigation

1. Why boiler accidents still matter on “modern” ships

Steam may seem old-fashioned in an era of electronic engines and hybrid power, yet auxiliary and exhaust

gas boilers remain central to many ships. They support cargo heating, tank cleaning, fuel conditioning, inert gas generation and accommodation services. A boiler incident, therefore, affects both safety and commercial performance.

Furnace explosions and blowbacks can injure crew, damage furnace walls and uptakes and put the vessel off-hire. Tube failures and fires can lead to flooding of the engine room with smoke, rapid escalation of damage and extensive downtime. Even a “minor” flame failure can indicate serious deficiencies in combustion control, fuel



handling, or safety interlocks that may later manifest as a major casualty.

The amount of heat damage at the scene often complicates the investigation of boiler accidents. This makes it essential to have a precise investigative method, rooted in how combustion systems should work and how international codes expect them to be designed and operated.

2. The marine steam system in brief

On a typical bulk carrier or tanker, the steam system includes:

- One or more **auxiliary oil-fired boilers** (water tube or fire tube) for port and low-load operation.
- An **exhaust gas boiler or economiser**, using main engine exhaust to generate additional steam at sea.
- **Burner management systems** (BMS) controlling ignition, fuel valves, purge sequences, flame detection and safety shutdown.
- **Combustion control systems** regulating fuel and air (often with O₂ trim and load control).
- Fuel oil supply, including **viscosity control, heating, filtration and change-over systems** for different grades.

A good investigator treats the boiler not as a single unit that “exploded”, but as an integrated system where fuel preparation, air supply, ignition, safety interlocks, control logic and human actions all interact.

3. Typical accident modes: what actually goes wrong

Most serious incidents fall into a few recurring patterns:

1. Furnace explosion or blowback

- o Unburned fuel or fuel vapour accumulates in the furnace due to repeated misfires or a failed purge.
- o Ignition finally occurs, creating a pressure wave that can damage doors, brickwork and uptake and injure nearby crew.

2. Tube failure and fire

- o Overheating due to poor water circulation, heavy soot deposits, or incorrect firing rates causes tube metal to weaken and rupture.
- o Escaping steam, fuel, or hot gases can ignite nearby combustible material and cause secondary fires.

3. Backfiring and refractory damage

- o Poor burner alignment, distorted registers, or uneven air distribution cause flame impingement and refractory spalling.
- o Cracked refractory then leads to local overheating of pressure parts and further deterioration.

4. Control failure with dry-firing risk

- o Faulty level control or bypassed alarms lead to operation with dangerously low water level.
- o If not caught, this can lead to severe overheating of furnace crowns and possible catastrophic rupture.

The recurrent themes behind these events are combustion control faults, unsafe fuel conditions, safety

devices not operating as intended and inadequate operator understanding of the control philosophy.

4. Combustion control faults: reading the sequence

When a blowback or combustion incident occurs, the first investigative task is to reconstruct the **ignition and firing sequence** leading up to the event. Key steps include:

- Collecting burner management system logs, alarm histories and any trend data for fuel pressure, air flow and O₂ readings.
- Interviewing the watchkeepers about what they observed: number of failed ignitions, abnormal noises, smell of unburned fuel and visible flame conditions.
- Checking **purge timing and logic**: was the furnace purged for the correct duration and air flow between ignition attempts, or was the purge bypassed or shortened to “save time”?
- Verifying **flame detector condition and alignment** and whether flame failure alarms and trips operated correctly.



In many cases, the underlying fault is not the violent explosion itself but the failure of the system to **refuse to try to light** when conditions were unsafe. For example, repeated failed starts with a weak spark and marginal atomisation may have been allowed to continue, building up a flammable mixture in the furnace.

The investigator should examine whether:

- The combustion control system was properly tuned for the actual fuel viscosity and burner condition.
- Air registers and dampers were free to move and correctly set.
- Manual interventions by crew (such as forcing starts or overriding trips) contributed to unsafe conditions.

A forensic review of control logic and setpoints often reveals that commissioning settings have drifted significantly over time, or that crew have adopted “work-around” routines when faced with nuisance trips, unintentionally eroding safety margins.

5. Fuel quality issues: what was burning when it blew back

Fuel quality plays a very significant role in burner performance and stability. Investigation should look

beyond the bunker delivery note to the real conditions at the burner tip:

- Was the fuel within the specification ordered and were there any signs of **contaminants, water, or instability** that might affect atomisation and ignition?
- Were heating and viscosity control systems operating properly, or was the fuel either too cold and viscous or too hot, leading to vapour lock?
- Were filters and strainers clean, or was the burner struggling against partial blockage, resulting in poor spray patterns and delayed ignition?

Sampling and laboratory analysis can highlight off-spec fuel, high asphaltene content, or contamination with non-conventional components. These may not be the direct cause of a single blowback, but they often contribute to **unsteady combustion**, flameouts and recurrent misfires.

The chain of causation can be subtle. Poor fuel quality leads to unstable flame; unstable flame leads to frequent ignitions and shutdowns; repeated ignition attempts with inadequate purge eventually create conditions for an explosion. Recognising this chain is vital when apportioning responsibility between owners, charterers, fuel suppliers and crew.

“
*Modern Boilers Still
Explode Because Old
Habits Refuse to Die*
”

6. Safety interlocks: the protections that should have saved the day

Boilers are designed with several layers of protection. Typical interlocks and safeties include:

- **Low and very low water level trips** to prevent firing on an empty or near-empty boiler.
- **High furnace pressure trips** to detect explosions or blocked uptake.
- **Low combustion air pressure trips** to avoid firing without adequate air.
- **Fuel shutoff valves** that must fail-safe and close upon loss of power or control air.
- **Ignition sequence interlocks** ensuring correct purge, pilot and main flame establishment before full firing.

The investigation must establish, with evidence, whether these interlocks:

- Were correctly set and functioning immediately before the incident.
- Had been bypassed, mechanically or in software, for maintenance or convenience.



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- Generated alarms or trips that were acknowledged but not acted upon.

It is not uncommon to find that a safety device was disabled months earlier to address a nuisance alarm and was never restored. In such cases, the failure is less a technical one and more a systemic breakdown in the Safety Management System.

7. Post-incident reconstruction

Even when large parts of the boiler and burner assembly are damaged, careful reconstruction can yield a coherent picture:

- Examination of **fracture surfaces** can reveal whether damage originated from inside the furnace (typical of an internal explosion) or from external overpressure or structural deformation.
- The pattern of deformation on doors, hatches and uptakes can indicate the direction and magnitude of the pressure wave.
- Residue patterns, soot deposits and the presence of **unburned fuel or atomising steam traces** can indicate at what point in the firing sequence things went wrong.
- Reassembly of burner components in a workshop setting can help assess alignment, wear and mechanical integrity.

This physical reconstruction must be cross-checked against the control system and alarm logs, as well as crew testimony. Inconsistent timelines are a warning that some assumptions are wrong or some evidence is incomplete.

8. Case study 1: Auxiliary boiler blowback in port

In the first illustrative case, a geared bulk carrier in port suffered a violent blowback during an attempt to start the auxiliary boiler for cargo heating. The furnace door was damaged and two crew members in the vicinity suffered burns and hearing injuries.

The investigation established that:

- The boiler had been idle for several days and there was a known issue of **sticky fuel valves**, leading to occasional misfires.
- During the morning of the incident, the watch engineer attempted several start cycles in quick succession to “get it going” for cargo operations.
- Correct pre-purge duration, as per the manual, was 30 seconds at full forced-draught; actual purge times observed in the BMS log were closer to 10 seconds, interrupted by repeated attempts to ignite.
- The flame scanner was found to be contaminated and misaligned, with borderline sensitivity.
- The forced-draught air fan inlet filter was partially blocked, reducing effective purge air flow.

Analysis concluded that unburned fuel had progressively accumulated in the furnace. When ignition finally occurred and a slightly richer mixture was present, a flame front propagated through the fuel-air mixture, triggering an internal explosion.

Legally, the owner faced claims under crew injury, class requirements for boiler repair and re-commissioning and several days of off-hire while repairs and surveys were completed. The investigation found that procedures required by the ISM Code for testing safety devices and for adhering to purge times were not followed; a non-conformity was raised and the company had to implement revised training and stricter supervision of boiler start-up procedures. While the fuel supplier was questioned, the primary cause was attributed to shipboard practice rather than fuel quality.

9. Case study 2: Exhaust gas boiler fire and extended off-hire

In the second case, a large bulk carrier experienced an exhaust gas boiler fire shortly after departing a high-

traffic port. The fire was brought under control using fixed water spray and manual intervention. Still, the boiler was severely damaged and had to be isolated, leaving the vessel dependent solely on the auxiliary boiler.

Investigation findings included:

- Heavy **soot and unburned oil deposits** inside the exhaust gas boiler, attributed to prolonged low-load operation of the main engine and inadequate soot-blowing routines.
- A recent period of off-spec fuel with poor ignition characteristics, leading to increased smoke and incomplete combustion at the main engine.
- Evidence that the high exhaust gas temperature alarm had been acknowledged multiple times on previous voyages without effective corrective action.
- A malfunctioning **exhaust gas temperature monitoring loop**, resulting in delayed or absent trips for runaway temperatures.
- Temporary isolation of one thermal monitoring device during earlier maintenance, which had not been properly re-commissioned.

The fire likely started when deposits ignited at high exhaust temperatures, propagated along the gas path and damaged the tube bundle and casing.

Financial consequences were significant. The ship spent several weeks at a repair yard, where the boiler and related ducting were replaced. The charterer placed the vessel off-hire for the entire period and claimed additional costs for delays. Insurers scrutinised the operator's maintenance records and ISM implementation, focusing on repeated alarms and missed opportunities to clean the boiler or adjust engine load profiles. The final settlement apportioned liability between the owner's negligent maintenance (failure to manage soot deposits and alarms) and, to a lesser degree, fuel quality issues. The case underscored that having an exhaust gas boiler alone is not risk-free: without proactive management of fuel, load and soot, it can become a fire hazard.

10. Regulatory and class framework

Boiler accident investigations sit within a clear regulatory context. SOLAS Chapter II-1 sets requirements for machinery and boiler installations that ensure safety regarding design, construction and operation, including safeguards against overpressure and overheating. SOLAS Chapter II-2 addresses fire safety in machinery spaces, including the need for reliable detection, fixed fire-extinguishing systems and safe arrangements for oil-fuel-burning equipment. The ISM Code requires companies to establish procedures for critical equipment maintenance, for investigating non-conformities and incidents and for implementing corrective actions across the fleet. Classification society rules supplement

these conventions with detailed requirements on boiler design, safety systems, control arrangements and survey intervals.

In the aftermath of a boiler casualty, investigators will therefore consider not only the technical failure but also whether the ship was operated in conformity with these obligations. Were safety devices tested at the prescribed intervals and records kept up to date? Was there a trend of relevant alarms or near misses that prompted no deeper investigation? Were the manufacturer's instructions for burner tuning and fuel conditioning observed? These questions directly influence findings on due diligence and seaworthiness, which in turn determine the extent to which owners can rely on contractual or statutory defences.

11. Lessons for owners and engineers

Boiler incidents, especially blowbacks and fires, are often described as "sudden" events. In reality, they usually represent the visible end of a long chain of small technical faults, operational shortcuts and ignored warnings. For marine engineers and ship managers, the key lessons include:

- Treat burner management and combustion control systems as **safety-critical** and manage setpoint changes through a formal process, not ad-hoc adjustments.
- Take fuel quality seriously, from bunkering to burner tip, especially when operating at low loads or with new blends.
- Protect safety interlocks from casual bypass and ensure any temporary overrides are tightly controlled, documented and removed promptly.
- Use alarms as **early-warning tools**, not background noise. Patterns of repeated boiler-related alarms deserve full root cause analysis.
- Embed boiler incident scenarios into drills and training, so engineers know exactly how to respond when a flame failure or furnace pressure alarm appears at the worst possible moment.

When investigated with discipline and a systems mindset, each boiler accident becomes a powerful learning event. In the long run, that learning is worth far more than the steel that had to be replaced and it is the only reliable way to reduce the human, legal and financial cost of the next blowback.

About the Author



Capt. Gajanan Karanjikar, Master Mariner and US-based casualty investigator, brings decades of sea and shore experience in vessel command, surveys and forensic investigations, advancing safety, seamanship and compliance globally.

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4. Has at least three months of approved sea going service on chemical tankers Within the last sixty months on Chemical tankers, or at least one month of approved onboard training on Chemical tankers on a supernumerary capacity, which includes at least three loading and three unloading operations and is documented in an approved training record book as specified in section B-v/1 of the STCW Code.

| | | |
|--|---------|--|
| Advanced Training for Chemical Tanker Cargo Operation | 10 days | 18 th May 2026 – 28 th May 2026 |
|--|---------|--|

VENUE: IMEI HOUSE, Plot No.94, Sector-19, Nerul, Navi Mumbai- 400706

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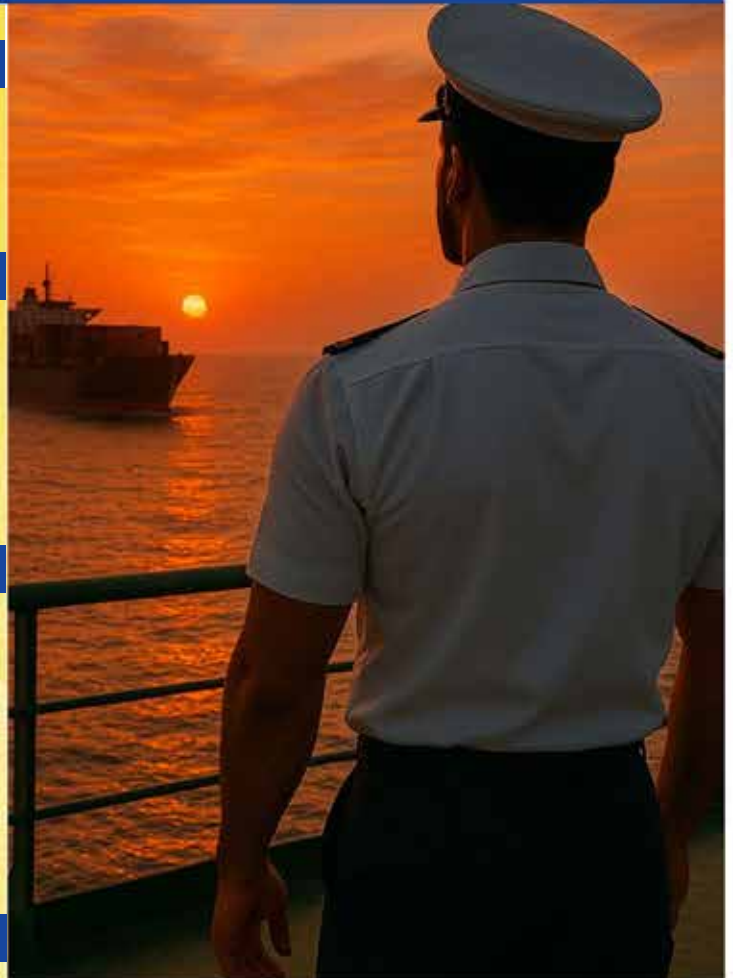
City College

(Post Sea Training Centre)



AMET, the Pioneer of Maritime Education with 32 + years of existence announces its expansion into the furtherance of Seafarers Career Path through AMET CITY COLLEGE, a Post Sea Training Institution situated at Villivakkam, the heart of the Chennai City.

| S.NO | ID | COURSE | Duration |
|---------------------------------|------|---|----------|
| ENGINE ROOM SIMULATOR | | | |
| 1 | 3241 | Diesel Engine Combustion Gas Simulator MEO Class I | 3 Days |
| 2 | 3221 | Engine Room Simulator - (Management level) MEO Class II | 5 Days |
| 3 | 3121 | Engine Room Simulator - (Operational level) MEO Class IV | 3 Days |
| NAVIGATION SIMULATOR | | | |
| 4 | 4211 | Global Maritime Distress Safety System (GMDSS) | 12 Days |
| 5 | 2121 | Radar Observer Simulator - (ROSC) | 10 Days |
| 6 | 2122 | Automatic Radar Plotting Aids - (ARPA) | 5 Days |
| 7 | 2123 | Electronic Chart Display And Information Systems - (ECDIS) | 6 Days |
| 8 | 2221 | Radar And Navigation Simulator (RANSCO) | 6 Days |
| ADVANCED MODULAR COURSES | | | |
| 9 | 5312 | Advanced Training for Ships using Fuels covered within IGF code (AIGF) | 5 Days |
| 10 | 5112 | Advanced Training for Oil Tanker Cargo Operations (TASCO) | 10 Days |
| 11 | 5122 | Advanced Training for Gas Tanker Cargo Operations (GASCO) | 10 Days |
| 12 | 5113 | Advanced Training for Chemical Tanker Cargo Operations (CHEMCO) | 10 Days |
| 13 | 1061 | Vertical Integration Course For Trainers - (VICT) | 10 Days |
| 14 | 6421 | Medical Care (MC) | 10 Days |
| BASIC MODULAR COURSES | | | |
| 15 | 5311 | Basic Training for Ships using Fuels covered within IGF code - (BIGF) | 4 Days |
| 16 | 3123 | High Voltage Safety And Switch Gear - (Operational Level) | 1 Days |
| 17 | 6101 | Basic Safety Training [BST= EFA+FPFF+PST+PSSR] | 12 Days |
| 18 | 6621 | Security Trng. for Seafarer with Designated Security Duties - (STSDSD) | 3 Days |
| 19 | 5121 | Basic Training for Liquefied Gas Tanker Cargo Operations (BTLG) | 5 Days |
| 20 | 5111 | Basic Training for Oil and Chemical Tanker Cargo Operations (BTOC) | 7 Days |
| 21 | 5211 | Crowd Management, Passenger Safety & Safety Training - (PSF) | 3 Days |
| 22 | 6511 | Ship Security Officers - (SSO) | 3 Days |
| 23 | 6411 | Medical First Aid (MFA) | 4 Days |
| REFRESHER COURSES | | | |
| 24 | 1118 | Revalidation / Refresher and Updating Training for Engineers and ETO (REO) | 4 Days |
| 25 | 6412 | Refresher Training in Medical First Aid Course (RMFA) | 1 Day |
| 26 | 6122 | Refresher Training for Proficiency in FPFF | Half Day |
| 27 | 6112 | Refresher Training for Proficiency in PST | Half Day |



| COMPETENCY COURSES | | | |
|---------------------------|------|----------------------------|----------|
| 28 | 3231 | MEO Class I | 2 Months |
| 29 | 3211 | MEO Class II | 4 Months |
| 30 | - | MEO Class IV (Value Added) | 2 Months |
| 31 | 2211 | Chief Mate (FG) Phase - I | 3 Months |
| 32 | 2212 | Chief Mate (FG) Phase - II | 3 Months |
| 33 | 2111 | Second Mate (FG) | 4 Months |

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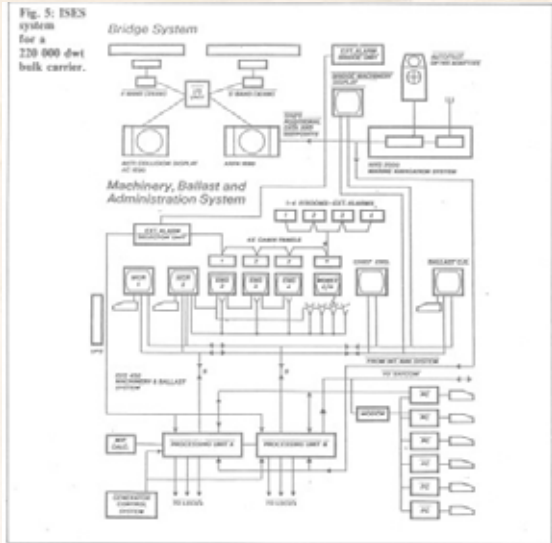
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engine protection—meeting the demands of increasingly poor-quality marine fuels.

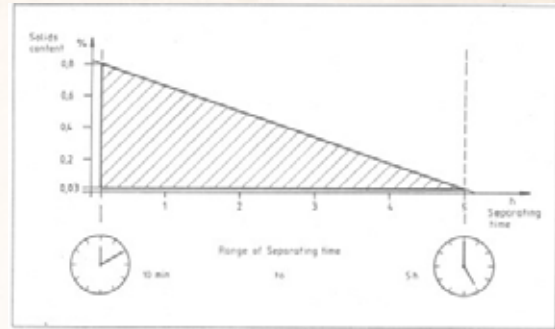


Fig 1: Depending on the solids content, separation can range between 10 min and 5h.

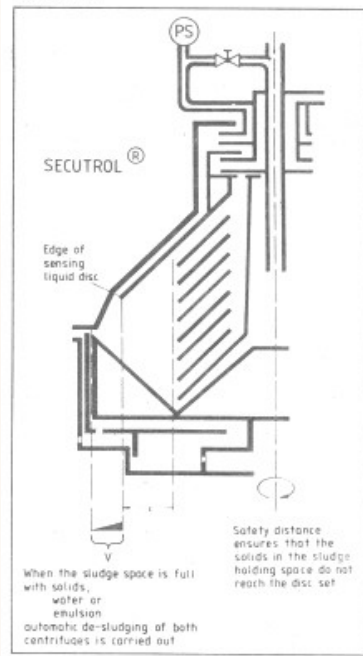
Information gleaned from a world-wide fuel testing service - D Royle, BSc, C Eng, MIMarE, AMRAeS, DNV.

The article analyses global bunker fuel test data, highlighting wide quality variations, frequent viscosity and contamination issues, and the growing importance of independent fuel testing in protecting engines, supporting claims, and shaping international marine fuel standards. The first edition of marine fuel quality standard ISO 8217 was published in 1987.

It was issued by the International Organization for Standardization to establish globally harmonised specifications for marine distillate and residual fuels, replacing fragmented national and industry standards.

This was a consequence of need to standardise specifications of marine fuel due surge in poor-quality residual fuels in 1980's

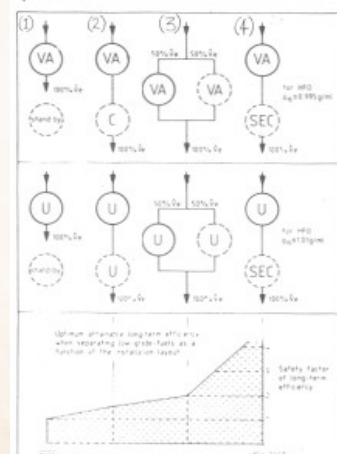
Fig 2: Secutrol clarifier with 'self-thinking' control system.



Treatment by “Self-Thinking” Purifiers by F. J. Loddenkemper, CEng, FIMarE

The article examines the evolution of “self-thinking” centrifugal fuel separators that automatically adjust desludging and separation parameters based on fuel properties and contamination levels. It explains how variations in viscosity, density, water content, and catalytic fines affect separator performance, and shows how adaptive control improves efficiency, reduces oil losses, minimises wear, and prevents unsafe operating conditions. Practical comparisons with conventional time-based separators demonstrate improved reliability, safety margins, and continuous operation for modern marine fuel treatment systems. Adaptive, “selfthinking” centrifugal separators represent a major advance in marine fuel treatment. By responding automatically to real contamination levels, they provide safer operation, improved efficiency, reduced maintenance, and better

Fig 3: (1) one Varzone purifier in single operation (2) one Varzone purifier and a standard clarifier in two-stage operation (3) two Varzone purifiers in parallel operation (4) one Varzone purifier and one Secutrol clarifier in two-stage operation.



| Limiting quantities | Variants | | |
|--|--|--|--|
| Shape | spherical or drop shaped | irregular shapes | lamellar fibrous |
| Size | 20µm | 6-20µm | 1-5µm |
| Density of foreign matter or density difference between foreign matter and feedstock | large | medium | small |
| Type | heavy metal | light metal, sand | wood, fibrous matter |
| Advantage | solid, crystalline, liquid e.g. free water in oil | soft, amorphous | streaky, fibrous |
| Disadvantage | low | medium | high |
| Sea water and water-soluble salts, e.g. Na, Ca | good desalination if no water in oil or very little water in oil | Medium desalination if no water in oil or very little water in oil | Desalination is difficult when there is a lot of water in oil or when the water is emulsified with the oil |
| Density | gas oil | low | medium |
| Viscosity | low | medium | high |
| Detergent and dispersant properties | low | medium | high |
| Solubility, water-absorbent capacity | low | medium | high |

Separating efficiency, expected effective throughput

Fig 4: Criteria for judging the separating efficiency and throughput capacity of centrifugal separators

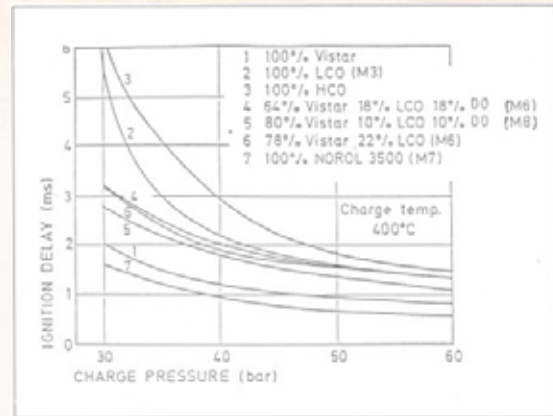


Fig 2: The ignition delay at 400°C and different charge pressures.

Table 3: Ignition delay at different temperatures and pressures.

| Charge Temp. (°C) | Pressure (bar) | Ignition delay (ms) | | | | | | |
|-------------------|----------------|---------------------|------|------|------|------|------|------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 350 | 30 | 2.3 | 16.0 | 17.0 | 3.9 | 3.8 | 3.5 | 2.2 |
| | 40 | 1.7 | 3.6 | 4.5 | 2.7 | 2.05 | 2.20 | 1.3 |
| | 50 | 1.4 | 1.6 | 3.1 | 1.9 | 1.35 | 1.45 | 0.85 |
| 400 | 30 | 1.0 | 1.2 | 1.6 | 1.35 | 1.35 | 1.40 | 0.7 |
| | 40 | 2.0 | 6.0 | 6.0 | 3.15 | 2.50 | 3.15 | 1.6 |
| | 50 | 1.0 | 1.6 | 1.8 | 1.55 | 1.95 | 1.80 | 0.95 |
| 400 | 50 | 1.0 | 1.6 | 1.8 | 1.55 | 1.45 | 1.55 | 0.85 |
| | 60 | 0.75 | 1.3 | 1.3 | 1.20 | 1.15 | 1.25 | 0.6 |

Table 4: Engine results—ignition delay and max rate of pressure rise.

| Rev/min | Pme bar | Test No. | Test fuel No. | | | | | | | | |
|---------|---------|----------|---------------|------|------|------|---------|------|------|------|------|
| | | | 4 | 5 | 6 | 7 | Str run | | | | |
| 750 | 18 | 1 | 1.00 | 7.3 | 0.88 | 5.7 | 0.88 | 8.4 | 0.77 | 5.3 | 0.68 |
| 750 | 10 | 2 | 1.06 | 8.8 | 1.44 | 19.2 | 1.55 | 20.0 | 1.33 | 7.5 | — |
| 559 | 10 | 3 | 2.2 | 22.4 | 1.79 | 10.9 | 1.79 | 18.0 | 1.64 | 12.4 | — |
| 750 | 4 | 4 | 2.0 | 22.0 | 1.77 | 6.3 | 1.88 | 8.2 | 1.96 | 9.0 | 1.11 |
| 334 | 4 | 5 | — | Z= | 2.11 | 4.9 | 2.35 | 6.8 | 1.88 | 10.4 | — |

The readers are advised / encouraged to go through IME(I) website where the MER(I) archives is available for viewing. This will help us understand that maritime industry is part of the continuum of shared ideas and opinions of the past and present and our present discussions lay foundation pillars for future discussions.

Diesel Engine Combustion Research in Norway - Geir Fiskaa Assistant Professor, Marine Engineering Norwegian Institute of Technology (NTH), Trondheim

The article reports Norwegian research into diesel engine combustion using poor-quality marine fuels. It shows how refinery-driven changes in fuel composition, especially high aromatic content from LCO and decanted oil, increase ignition delay and affect combustion behaviour. Laboratory and engine tests demonstrate the influence of temperature, pressure, and blending on ignition quality and pressure rise. The study highlights operational risks from poor fuels and stresses the need for improved fuel testing, pretreatment, and onboard assessment tools to ensure reliable engine operation. Refinery-driven changes in marine fuel composition significantly affect ignition and combustion behaviour. While higher pressures and temperatures improve ignition, fuel chemistry remains the dominant factor. Reliable operation with poor fuels requires improved testing, monitoring, and fuel treatment strategies.

Table 1: Specification of the three fuel fractions.

| | Vistar | LCO | DO |
|----------------|-------------------|------|------|
| Viscosity/40°C | cSt | — | 3.3 |
| Viscosity/50°C | cSt | 3830 | — |
| Density/15°C | kg/m ³ | 992 | 1047 |
| Water | % | 0.1 | 0 |
| CCR | % | 22.1 | 0.13 |
| Sulphur | % | 2.3 | 0.72 |
| Ash | % | 0.03 | 0 |
| Vanadium | ppM | 110 | 0 |
| Sodium | ppM | 20 | 0 |
| Aluminium | ppM | 0 | 0 |
| Silicon | ppM | 2 | 0 |

Table 2: Test fuels—mixtures, viscosities and densities.

| Test fuel No. | Vistar Vol % | LCO Vol % | DO Vol % | Density kg/m ³ 15°C | Viscosity cSt/50°C | BS MA100 Class |
|---------------|----------------------|-----------|----------|--------------------------------|--------------------|----------------|
| 1 | 100 | — | — | 992 | 3830 | — |
| 2 | — | 100 | — | 928 | 3.3 (40°C) | (M3) |
| 3 | — | — | 100 | 1047 | 77 | — |
| 4 | 63.5 | 18.5 | 18 | 992 | 141 | (M6) |
| 5 | 80 | 10 | 10 | 989 | 394 | M8 |
| 6 | 78 | 22 | — | 976 | 175 | M6 |
| 7 | Straight run residue | | | 966 | 358 | M7 |

We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages. – Hon.Ed

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DG APPROVED MODULAR COURSES

| Sr. No. | Course Name | Course Fee | Course Duration | Course Schedule |
|---------|--|------------|-----------------|---|
| 1 | Basic Training for Oil and Chemical Tanker Cargo Operations (OCTF) | ₹7,250/- | 6 Days | 26 th February, 2026 21 st April, 2026 |
| 2 | Basic Training for Liquefied Gas Tanker Cargo Operations (LGTF) | ₹7,250/- | 5 Days | 18 th March, 2026 29 th April, 2026 |
| 3 | Basic Training for Ships using Fuels covered within IGF Code (IGFB) | ₹12,550/- | 5 Days | 11 th March, 2026 1 st April, 2026 |
| 4 | Security Training for Seafarers with Designated Security Duties (STSDSD) | ₹4,050/- | 2 Days | 30 th March, 2026 13 th April, 2026 |
| 5 | Ship Security Officer (SSO) | ₹4,950/- | 3 Days | 26 th March, 2026 16 th April, 2026 |

- ◆ **Course Fee includes** lunch, two tea breaks, and one examination fee.
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RANKED GRADE A1 (OUTSTANDING)

D. G. Shipping Approved Course

05
Days

★ **Course Id - 5121**

Basic Training for Liquefied Gas Tanker Cargo Operations

Entry Criteria: Any seafarer who has successfully completed approved Basic Safety Training Course as per STCW Section A-VI/1. para 2.3. Tables A-VI/1-1. A-VI/1-2. A – VI/1-3. A-VI/1-4

- This Course will familiarize with the equipment, instrumentation and controls used for cargo handling on a Gas tanker. It will enhance the awareness to apply proper and safe procedures at all times when carrying out the various operations on board tanker
- The trainee will be able to identify operational problems and assist in solving them and will be able to co-ordinate actions during emergencies and follow safety practices and protect the marine environment.



Course Date:

11th – 20th April – 24th April 2026/ 9th May – 13th May 2026

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