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Reducing Marine Vessel Fuel Consumption and System Complexity: A Case for MDO and ORC Integration

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Abstract
Current marine operations heavily rely on Heavy Fuel Oil (HFO), dictated by cost and historical compliance, despite the high associated maintenance burden, system complexity, and environmental risks. This paper proposes a paradigm shift, advocating for the exclusive use of Marine Diesel Oil (MDO) on specific vessel types (such as MR Tankers, Bulk Carriers, and Container Vessels) combined with the strategic implementation of an Organic Rankine Cycle (ORC) for Waste Heat Recovery (WHR). The core concept involves the complete elimination of the conventional HFO treatment system—including the steam boiler, fuel oil purifiers, heaters, and auxiliary systems. This simplification is projected to yield significant operational savings by eliminating an estimated 3 tonnes of daily boiler fuel consumption and drastically reducing maintenance demands, leading to a lighter, cleaner, and more cost-effective vessel operation.

Keywords: Marine Efficiency, Organic Rankine Cycle (ORC), Marine Diesel Oil (MDO), Waste Heat Recovery, System Simplification.

1. Introduction: The Operational Burden of HFO

The maritime industry is under increasing pressure to improve operational efficiency and meet stringent environmental regulations. While HFO remains the primary fuel choice due to its low initial cost, its use necessitates complex ancillary systems: the steam boiler plant for heating and hot water, and the extensive centrifugal purification system required to clean the fuel and maintain engine safety. These systems introduce substantial operational costs through:

1. **Parasitic Fuel Consumption:** The continuous operation of the boiler consumes significant fuel, typically MDO or HFO itself, for heating and services.
2. **High Maintenance and System Complexity:** Purifiers are known for frequent overhauls, and boilers require continuous water treatment, burner maintenance, and mandatory class inspections every 2.5 years, diverting engineering resources.

This paper challenges the necessity of these systems by proposing a structural solution that transitions to MDO and leverages existing waste heat.

2. Proposed Methodology: The MDO-ORC Paradigm

The proposed system rests on two pillars: the exclusive adoption of Marine Diesel Oil (MDO) and the incorporation of an Organic Rankine Cycle (ORC) for electrical power generation.

2.1. Fuel Transition and System Simplification

The shift to MDO (or other low-sulphur distillate fuels) removes the fundamental need for heating the fuel supply. Key components that can be immediately eliminated include:

- **HFO Purifier System:** The entire purification train (heaters, purifiers/separators, settling tanks, associated transfer pumps, and viscometers) becomes redundant. This removes a major source of system failure and a high-frequency maintenance task.
- **Boiler and Auxiliary System:** The boiler, forced draft fan, circulation pumps, and complex water treatment equipment are completely removed, dramatically reducing weight and freeing up engine room space.

Minor heating loads, such as the calorifier, lube oil purifier, and other small heaters, will be handled by highly efficient, small-scale electric heating elements powered by the vessel's electrical grid.

2.2. Waste Heat Recovery via Organic Rankine Cycle (ORC)

With the boiler eliminated, the vessel must find an alternative, more efficient method to meet its thermal and electrical demands. The solution is to install a dedicated ORC unit designed to recover heat from the main engine exhaust gas.

Unlike conventional steam turbines, the ORC utilizes an organic fluid with a low boiling point, enabling highly efficient recovery of lower-grade heat from sources like engine jacket water, scavenger air, or exhaust gas.

In the case of an MR Tanker operating at full ahead with a Main Engine (ME) consumption of 18 tonnes per day, a significant amount of heat is available in the exhaust stream. The ORC converts this recovered heat directly into electrical energy. This supplementary power can be utilized to cover non-essential loads (e.g., accommodation lighting) or to partially offset the load on the Auxiliary Engines (AE). Given the typical AE consumption of 2.5 tonnes per day, even partial load reduction translates directly into fuel savings.

3. Operational and Economic Analysis

The adoption of the MDO-ORC solution offers cascading benefits across maintenance, efficiency, and cost:

Category	**HFO/Boiler System (Current)**	**MDO/ORC System (Proposed)**	**Benefit**
Boiler Fuel Consumption	~3.0 TPD (Daily consumption for an MR Tanker)	0 TPD	**3.0 TPD Direct Fuel Saving**
HFO Purifier Requirement	Mandatory (Heater, Centrifuge, Pumps, Viscotherms)	Not Required	Elimination of maintenance and complex systems.
Required Heating	Extensive lagging/insulation required on fuel lines.	No fuel line heating or lagging required.	Reduced installation cost and thermal losses.

Engine Room Cleanliness	Poor (Sludge handling, HFO leaks, boiler soot).	Excellent (MDO is inherently cleaner).	Reduced cleaning costs and improved safety.
Cylinder Lubrication	High TBN Cylinder Oil (Required to neutralize HFO acidity).	Low TBN Cylinder Oil	Reduced cylinder oil consumption and cost.
Maintenance Cycle	Boiler 2.5-year inspection, frequent purifier overhauls.	Virtually eliminated for boiler/purifier systems.	Significant reduction in crew workload and spares cost.
Vessel Weight	Boiler, FD Fan, heavy HFO storage/settling tanks.	Reduced overall deadweight.	Improved cargo capacity or reduced lightship displacement.

The most compelling economic benefit is the elimination of the 3 TPD boiler consumption. While MDO may carry a higher unit cost than HFO, the total system efficiency gain, combined with the elimination of extensive maintenance (spares, labor, drydock costs), makes the MDO-ORC ship design a superior cost-effectiveness idea. Furthermore, operating on MDO ensures easy compliance with all regulatory areas, making the vessel a truly "clean ship" operationally.

4. Conclusion

The pursuit of marine cost-effectiveness demands a move away from legacy systems tethered to the complexities of HFO. The MDO-ORC paradigm offers a forward-looking blueprint for a simplified, efficient, and environmentally compliant vessel. By eliminating the steam boiler and HFO purification system, vessels like MR Tankers can immediately realize a saving of 3 tonnes of fuel daily, reduce their maintenance footprint, and enhance operational reliability. This integrated approach, which leverages ORC technology to harness otherwise wasted thermal energy, represents a significant step toward future-proofing vessel design and operations.