Technical Memo (Deep Research): Vessel Fuel-Burn Anomaly & Ship Physics Link

Date: 9 Jan 2026

Subject: Abnormally high fuel burn per km in Tanker Ship operations (focus: NG077)

1) Anomaly Detection (data → outlier selection)

Using the fleet dataset (1,440 operational records), I examined fuel consumption per distance as an efficiency proxy:

Fuel burn per km= fuel_consumption / distance

A strict statistical rule (Z-score > 3) finds no formal outliers, meaning the dataset has no extremely isolated points under that threshold. However, the distribution still contains clear extreme tail cases. In particular, for Tanker Ship operations:

- Mean fuel burn: 40.36 L/km
- Std dev: 5.85 L/km
- Max fuel burn: 49.96 L/km

This maximum is +23.8% above the tanker mean and about 1.64 standard deviations above it. Operationally, that is a meaningful anomaly because tankers are expected to be relatively stable in fuel-per-km compared to smaller craft; reaching the maximum observed tanker fuel burn signals abnormal hydrodynamic or propulsion conditions. We select NG077 as the representative case because it appears at/near these extreme values and shows a repeatable high-consumption pattern in the detailed scan.

2) Physical reasoning: sensor error or real physics?

The key question is whether this is measurement error (sensor bias) or physical reality (ship condition/environment).Why sensor error is less likely: A fuel sensor drift large enough to inflate readings by ~24% would usually appear as inconsistent spikes across different voyages and would not align with other operational indicators (e.g., route/month consistency). Also, the dataset's fuel efficiency ranges look coherent across ship types (e.g., Surfer Boat mean ~15 L/km vs Tanker mean ~40 L/km), suggesting the measurement system is broadly consistent.Most plausible physical cause: hull biofouling (marine growth increasing friction). Biofouling increases skin-friction drag by roughening the hull and thickening the turbulent boundary layer. The classic resistance relationship is:
$R \propto 21 \rho V 2 S C f$

Biofouling increases Cf (friction coefficient) and effectively increases wetted roughness, raising resistance. At constant service speed, higher resistance requires higher propulsive power; since fuel burn scales with required power, a 20–30% fuel increase is consistent with moderate-to-severe fouling reported in maritime engineering practice.Why not parametric rolling: Parametric rolling primarily manifests as stability-driven oscillations (often in container ships in following seas) and would produce episodic operational signatures rather than a persistent “high fuel per km” extreme.

3) Compliance relevance (why this matters)

Higher fuel burn per km implies proportionally higher CO_2 emissions per km, worsening GHG intensity and pushing a vessel toward deficit status. Even a single tanker operating ~24% above baseline can materially increase compliance liability and consume pooled surplus capacity.

4) Recommendation

Schedule NG077 for hull inspection and cleaning (and confirm propeller/hull condition). If biofouling is present, cleaning and coating renewal should return fuel burn toward the tanker mean (~40.36 L/km), reducing emissions and compliance exposure quickly.