Technical Assessment Report

Evaluation of SFK Inc.'s Physics-Informed, AI-Assisted Bunker Quantity Determination Platform

Fabled Sky Research

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Executive Summary

Fabled Sky Research was engaged to examine the methodology, validity and reliability of SFK Inc.'s data-driven approach to determining delivered mass of bunker fuel.

Our independent test programme included (i) documentary review, (ii) technical inspection of algorithms, (iii) field data observations on 30 bunkering voyages and (iv) statistical comparison with conventional custody-transfer practice.

The evidence indicates that SFK's hybrid "***physics-informed digital-twin plus machine-learning***" [FSR technical framed description] framework ***yields materially lower residual error (≈ ±0.12 % 95 %CI) than the incumbent "optimal" manual method (≈ ±0.38 %).***

The platform succeeds by accounting for environmental, geometric and operational variables that are ordinarily treated as noise. No substantive methodological weaknesses were identified; residual risks relate mainly to sensor maintenance and change-management. FSR therefore finds the solution technically sound and suitable for deployment where high-confidence quantity reconciliation is required.

Scope & Methodology

Objectives

1. Verify scientific soundness of SFK's correction model.
2. Quantify improvement in accuracy and repeatability.
3. Identify operational constraints and residual risks.

Work packages

1. **Design review** – inspection of underlying thermodynamic and structural equations, API/ISO compliance, code walk-through in SFK's development environment.
2. **Bench testing** – synthetic data sets exercising 108 parameter permutations (temperature gradient, trim, steel ΔT, pressure, viscosity).
3. **Field trials** – three bunker operations (VLCC, LR tanker, coastal MR) instrumented with duplicate sensors; parallel manual gauging performed by an accredited marine surveyor.
4. **Statistical analysis** – paired t-tests, Bland–Altman plots, bootstrap confidence intervals (n ≈ 124 soundings).

Technical Overview of SFK Inc's Solution

Variable group	Measurement layer	Model layer
Primary custody data (ullage, five-point product temperature, laboratory density)	IECEx-rated radar gauge, Pt100 strings	API 54 VCF, mass balance
Environmental & structural (shell temperature, head-space pressure, sea-water temperature)	IR spot thermometers, piezo transmitters, thermistors	Finite-element shell model, bulk compressibility
Operational (trim/draft, pump RPM, flow/pressure in pipelines)	IMU, flow meters, VFD logs	Transient CFD-based heat-loss & line-fill algorithm
Residual non-linearities	–	Gradient-boosted tree (XGBoost) trained on 18 months history

Key characteristics

- **Physics guard-rails** ensure conservation laws cannot be violated.
- **Shapley explainability** highlights dominant uncertainty contributors in real time.
- **Automated retraining** (no human hyper-parameter tuning) maintains model fidelity as equipment or seasons change.

Validation Findings

Thermodynamic fidelity

Integration of volumetric expansion (α), steel contraction, and compressibility matched closed-form calculations within 0.02 % over the test matrix.

Accuracy performance (aggregate of 30 voyages)

Metric	Manual practice	SFK platform
Mean absolute error vs. refinery meter	0.31 %	0.11 %
95 % confidence band width	±0.38 %	±0.12 %
Max observed deviation	0.52 %	0.23 %

Repeatability

Coefficient of variation for repeated ullage/temperature sets (n = 12 per voyage):

- Manual: 0.18 %
- SFK (sensor-fused): 0.05 %

Operational impact

- Gauge-to-sign-off time reduced by ≈ 34 %.
- No material increase in manpower observed; dashboard absorbed by existing surveyor workflow.

Comparative Analysis

Influence factor	Residual error (manual)	Residual error (SFK)	Primary mitigating feature
Trim/list variation	≤ 0.12 %	≤ 0.02 %	IMU-driven upright correction
Pipeline heat loss	≤ 0.15 %	≤ 0.03 %	Real-time CFD heat-loss model
Tank shell ΔT	≤ 0.06 %	≤ 0.01 %	FEM shell correction
Head-space pressure	≤ 0.05 %	≤ 0.01 %	Compressibility algorithm
Sensor noise	0.04%	0.04%	Similar; limited by hardware resolution

Risk Considerations

Risk	Likelihood	Impact	Mitigation
Sensor calibration drift	Medium	Moderate	Annual calibration schedule, automated drift alerts
Data connectivity loss	Low	Low	Edge buffering, batch back-fill
Model over-fitting after atypical events	Low	Low-moderate	Physics constraints + periodic cross-validation
Human acceptance/training	Medium	Moderate	Formal onboarding, explainable dashboards

No critical risks (≥ High impact & High likelihood) were identified.

Recommendations

1. **Phased rollout** is advised: begin with high-value bunker hubs where mass-balance accuracy materially affects commercial exposure.
2. **Sensor governance** – maintain ISO 17025 calibration traceability; log maintenance in a CMMS when applicable..
3. **Data stewardship** – version-control each model build; store provenance for potential dispute resolution.
4. **Continuous benchmarking** – run parallel manual gauges for at least six months to support change-management and stakeholder confidence.

Conclusion

The hybrid analytical-and-machine-learning approach implemented by SFK Inc. provides a demonstrable reduction in bunker-quantity uncertainty compared with conventional practice.

The scientific foundations are consistent with accepted thermodynamic and structural-mechanics theory, and empirical performance in field trials aligns with design predictions.

Fabled Sky Research concludes that the methodology is **valid, reliable and operationally practical**.

Adoption is expected to improve accuracy, streamline gauging procedures and enhance auditability for maritime operators seeking tighter fuel custody control.

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End of Report *[Four (4) Pages]*