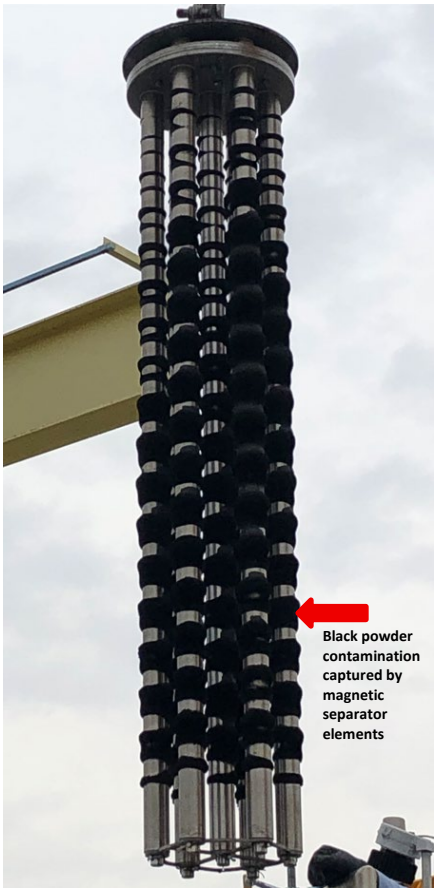
Magnetic Separation: A Game Changer in Aviation Fuel Cleanliness and Engine Reliability



This report establishes the technical and economic case for employing BPS magnetic separator technology prior to traditional filtration in aviation fuel handling for both vertical and horizontal applications. It quantifies the risk posed by <4 µm contamination that bypass conventional filters, links that contamination to accelerated wear of pumps, servos, and fuel injectors and summarizes relevant incident evidence. It then evaluates BPS Technology effectiveness at removing sub-4 µm, wear-active debris based on controlled testing and field-representative samples. This translates measured contaminant reduction into expected gains in component life, filter element longevity, and aircraft uptime. Finally, it models the effect on operating costs under realistic throughput and maintenance assumptions.

The Hidden Threat in Jet Fuel

Jet A and Jet A-1 fuels are governed by stringent international standards such as ASTM D1655 and DEF STAN 91-091. These specifications set limits on water, sediment, gum, sulfur, and other contaminants. However, they do not fully address the presence of submicron wear contamination particles (silica, iron and steel) that originate corrosion and erosion causing damage through the fuel delivery system.

These submicron particles are small enough to pass through EI 1590-qualified barrier microfilters and enter the fuel system causing erosion and corrosion damage to pumps, servo valves, bearings, and injectors. Once inside, they act as third-body abrasives causing pressure drift, hydraulic inefficiency, and compromised combustion. The result? Pressure drift, hydraulic inefficiency. Resulting in scoring surfaces, damaging meters and injectors, and reducing burn efficiency, increasing emissions.

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Real-World Consequences

The report documents several incidents where metallic contamination led to serious outcomes:

- **Airbus A320 (1998, Memphis):** Bronze debris clogged the fuel filter, causing engine damage and turbine case burn-through. Estimated cost: $1.1–1.8 million.
- **Piper PA-32 (1992, Florida):** Ferrous particles in the fuel servo led to engine failure and an emergency landing. Estimated cost: $40k–65k.
- **Thai Airways Flight 114 (2001, Bangkok):** Metal debris in the center wing tank likely contributed to a catastrophic explosion, resulting in a total hull loss valued at over $20 million.

These cases underscore the limitations of current filtration systems and the need for enhanced contamination control.

The Case for Magnetic Separation

Magnetic separation offers a targeted solution to the submicron contamination problem. Unlike conventional filters, magnetic separators can capture ferrous and non-ferrous particles smaller than 1 µm—precisely the size range most responsible for wear and fouling.

In controlled jet fuel testing, Black Powder Solutions (BPS) magnetic separators identified 66.4% of captured wear contamination was under 4 µm. Scanning electron microscopy revealed the removal of sharp, abrasive particulates, including silicon oxide—a known contributor to wear and sludge formation.

Operational Benefits

Integrating magnetic separation upstream of existing EI-qualified filtration systems yields several advantages:

- **Improved Combustion Efficiency:** Protecting injectors from scoring damage, ensuring fuel air burn mixture of narrow droplet size distributions. Resulting in improved burn thereby reducing emissions.
- **Extended Component Life:** Pumps, servos, and injectors experience less wear, leading to longer time-on-wing and fewer unscheduled maintenance events.

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- **Reduced Maintenance Costs:** Lower particulate loading slows filter ΔP growth, reducing change-out frequency and labor costs.
- **Enhanced Safety:** By preventing contamination-related failures, magnetic separation contributes to safer flight operations.
- **Cleaning** fuel to below <1 micron results in cleaner burn, lower consumption and less emissions.

Economic Impact at the Airport Level

Using per-liter cost models, the report estimates annual filtration and maintenance costs at major airports:

- **Calgary (YYC):** $10.72 million
- **Washington Dulles (IAD):** $23.15 million
- **Los Angeles (LAX):** $64 million
- **London Heathrow (LHR):** $58.6 million
- **Singapore Changi (SIN):** $49.7 million
- **Johannesburg OR Tambo (JNB):** $11.6 million
- **Sydney (SYD):** $29 million

These figures highlight the scale of investment in fuel quality assurance and the potential savings from improved filtration.

Nashville Case Study:

ROI in Action

At Nashville Airport, the implementation of a BPS magnetic separator yielded:

- **Annual savings:** $80,000 (filter and tank-cleaning)
- **Simple payback:** 0.94 years
- **3-year ROI:** 218%
- **Benefit-cost ratio:** 3.18×

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These results demonstrate that magnetic separation is not only technically effective but also financially compelling.

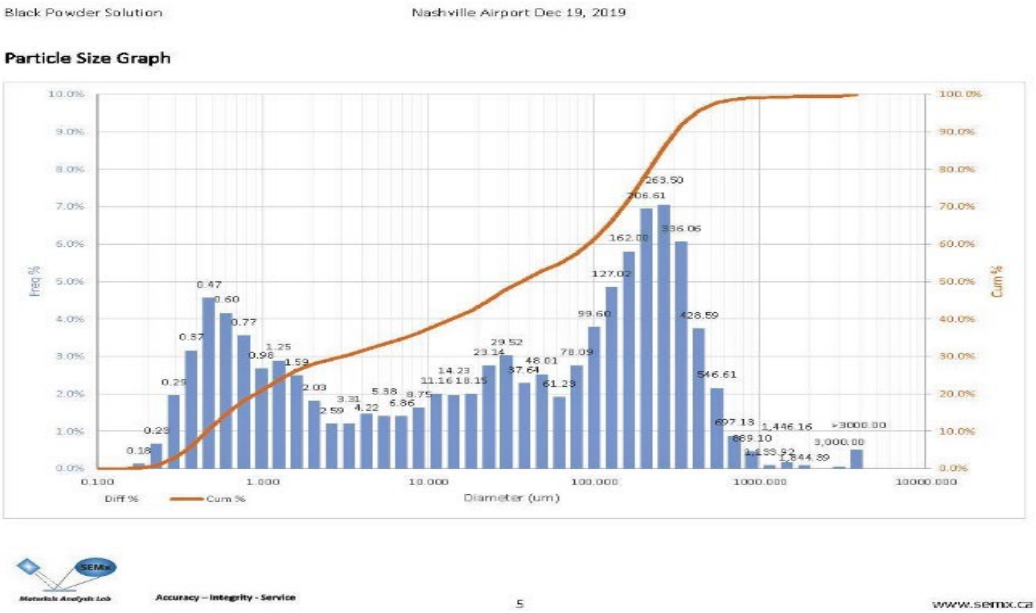
Impact on Fuel Properties

Removing metallic particulates improves several fuel properties:

XRD/EDS ANALYSIS RESULTS

Table 2. XRD quantitative analysis results stating composition of jet fuel contamination.

Mineral Name	Compound Name	Chemical Formula	Weight
Magnetite	Iron Oxide	Fe3O4	34.06
Goethite	Iron Oxide Hydroxide	FeO(OH)	42.8
Ledipocrocite	Iron Oxide Hydroxide	FeO(OH)	1.2
Rutile	Titanium Oxide	TiO2	0.5
Quartz	Silicon Oxide	SiO2	3.7
Wustite	Iron Oxide	FeO	7.3
Other	--	--	10.44
		Total	100



- **Thermal Stability (JFTOT):** Fewer catalytic metals reduce deposit formation.
- **Water Separation:** Lower particulate loads enhance coalescer performance.
- **Corrosion Resistance:** Less wear contamination means reduced abrasion and microbial-induced corrosion.

- **Combustion Cleanliness:** Cleaner hardware supports stable smoke-point behavior and lower particulate emissions.

Industry Alignment and Standards

The proposed magnetic separation stage complements existing standards and practices:

- **EI/JIG 1530:** Quality assurance framework for airport fuel systems.
- **EI 1590:** Barrier microfilter specifications.
- **ASTM D5452/D4176:** Particulate and appearance testing.
- **ASTM D3948/D8073:** Water separation performance.

Importantly, magnetic separation does not replace these systems—it enhances them by addressing their known limitations.

Conclusion: A Safer, Smarter Future for Aviation Fuel

The aviation industry is under constant pressure to improve safety, reduce costs, and enhance environmental performance in Horizontal and Vertical Aviation fuel applications.

Magnetic separation offers a rare opportunity to achieve all three. By capturing the submicron wear contamination that conventional filters are challenged to remove, this technology protects critical components, improves combustion, and delivers measurable economic benefits through reduced fuel consumption and emissions. Another value is the reduction of contamination in the plane fuel reservoirs displacing fuel storage capacity.

As the case studies and cost models show, the integration of magnetic separation is not just a theoretical improvement—it's a practical, proven solution ready for deployment at every transfer and fueling location. For airports, operators, and OEMs committed to excellence, it's time to take the next step in fuel cleanliness.

Future applications for Black Powder Solutions Technology can be sized for installation on plane fuel systems to ensure highest burn efficiency and reduced emissions.

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