CASE STUDY: Oil Filtration and Particle Removal in Sensitive Optics Cooling Air

Protecting Measurements, Hardware, and Emissions Integrity with a Multi-Stage, Maintainable Filtration System

Project Snapshot

Industry: Aerospace / Combustion Testing & Optical Diagnostics
Challenge: Contaminated cooling air was carrying oil and particles onto sensitive optics and into the combustor, risking hardware damage and biased emissions data.
Result: A dual-branch, multi-stage filtration system with health monitoring enabled ultra-clean air delivery, long filter life, and on-the-fly maintenance without interrupting testing.

---

1. Opening Hook – The Challenge

During an assessment of a client's combustion test cell, we observed that the **compressed air line used to cool optical instruments was visibly dripping oil**. This air also communicated with the exhaust-sampling environment, creating multiple, serious risks:

- Oil and particles contaminating **high-value optics**, degrading data quality and potentially damaging lenses or housings.
- Oil carryover into the flame, **artificially increasing NOx and other emissions**, compromising test validity.
- Local burning of oil deposits near the optical tips, risking hardware distress.

We immediately highlighted the issue and proposed a filtration solution tailored to the facility's duty cycle and operational constraints.

---

2. Problem Definition

The client needed a system that would:

1. **Remove oil and particulates** to protect optics and avoid emissions bias.
2. **Support long operating campaigns** (thousands of hours) without frequent filter changes.

3. Allow **filter maintenance while the test cell remained online**, avoiding experiment disruption.
4. Provide **clear health indicators** so maintenance could be planned, not reactive.

Simply inserting a single ultra-fine filter was not enough; it would clog quickly and drive up pressure drop and operating cost, a well-known issue in compressed-air treatment.

---

3. Our Approach – Dual-Branch, Multi-Stage Filtration

Redundant Two-Branch Layout

We designed a filtration manifold with **two parallel branches**, each isolated by its own pair of valves:

- **Primary branch:** Full multi-stage filtration for normal operation.
- **Secondary branch:** A simplified, fine-filtration path used only in **emergencies** (e.g., while cartridges are replaced in the primary branch).

This allowed the client to **switch branches live**, change filters without stopping the experiment, and continue running even if replacement elements were temporarily unavailable.

Three-Stage Filtration in the Primary Branch

The primary branch incorporated **three filtration stages**, each optimized for a different size range and contaminant type:

1. **Coarse/coalescing filter:**
   - Removes large particles and bulk oil droplets.
   - Extends life of the downstream fine elements.
2. **Fine filter:**
   - Targets smaller particles down to well below 1 μm (≈0.1 μm class).
   - Catches residual fines that pass the coarse stage.
3. **Ultra-fine/oil-removal stage:**
   - Captures remaining oil aerosol and sub-micron particulates.
   - Provides air that is **practically free of oil and particles**, suitable for sensitive optical systems and emissions-critical applications.

The **secondary branch** used a single fine-filtration stage. It wasn’t a full replica to save cost and complexity, but it was clean enough to protect the system during short maintenance windows.

Designed for Long Life

By sequencing coarse → fine → ultra-fine filters, we dramatically reduced loading on the most sensitive (and expensive) elements, consistent with best practices for compressed-air systems.

- With multi-stage protection, the system was designed to operate for **> 4,000 hours** before primary-branch filter replacement.
- A single ultra-fine filter alone would likely have required service in **< 500 hours**, increasing cost and downtime.

---

4. Monitoring and Maintenance Strategy

We integrated **differential-pressure monitoring** across each filter stage. When the pressure drop across any element exceeded approximately **7 psi**, the system flagged that it was time to service that filter.

This gave the client:

- **Real-time visibility** into filtration health.
- The ability to **plan cartridge changes** during convenient windows.
- Confidence that air quality remained within spec for both optics and combustion emissions throughout testing.

---

5. Takeaway & Forward Value

This project shows how **ProReady Engineering** approaches contamination control:

- We don't just bolt in a filter—we design a **system** that balances air quality, filter life, maintainability, and test-cell uptime.
- We use **multi-stage filtration and redundancy** to deliver ultra-clean air while avoiding over-filtration penalties and frequent change-outs.
- We consider the **downstream implications** of contamination on optics, hardware integrity, and emissions measurements, not just the local line we're modifying.

The result is a turnkey solution that **protects assets and data quality**, integrates smoothly with existing infrastructure, and gives the client clear, actionable information about system health.