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HVAC Systems: Airflow Measurement Tools and Verification Systems in Laboratory and Aseptic Processing Facilities

Introduction

Airflow measurement and monitoring are fundamental to reliable HVAC performance in laboratories and aseptic processing facilities (APFs). Supply and exhaust airflow data support required ventilation, room-to-room pressure relationships, personnel safety, product and process protection, and energy-efficient operation. Required pressure relationships depend on space use, process hazards, containment and product protection needs, and applicable regulatory and facility requirements. Permanent airflow measurement devices provide data to the building automation system (BAS) and associated controllers to support control sequences that respond to exhaust demand, process conditions, occupancy, operating mode, and changing outdoor air conditions. These devices must be properly selected, installed, commissioned, and verified at approved preventative maintenance intervals. Qualified personnel should perform verification using suitable reference instruments with current calibration records documenting measurement uncertainty and traceability to reference standards maintained by the National Institute of Standards and Technology (NIST).

Airflow Control Strategies

Airflow control strategies in laboratories and APFs must maintain required ventilation rates and pressure relationships while responding reliably to changes in process requirements, equipment operation, occupancy, and operating mode. Depending on the application, the design may use constant-volume or variable-volume control. Variable-volume control may use conventional variable air volume (VAV) terminal units, pressure-independent airflow control valves (including Venturi-type devices), or other suitable devices.

Airflow values supplied to terminal, room, or BAS controllers may come from airflow sensors or, for some control valves, from valve position and factory characterization. Controllers use these values and other inputs to adjust supply and exhaust airflow in response to operational demands. The BAS may record airflow, valve or damper position, fan status, static pressure, and room differential pressure over time, a practice known as trending. These records support troubleshooting and performance assessment, while configured alarms alert operators to conditions outside established limits. Airflow tracking may support room pressure control, but the required room-to-room pressure relationship should be independently verified by direct differential pressure measurement against the project-specified criteria.

Measurement Locations and Devices

Permanent airflow measurement may be provided at outdoor air intakes, supply and exhaust fan systems, main ducts and risers, branch ducts, and terminal units. An airflow measurement system (AFMS) uses sensing elements and an associated transmitter or controller to determine airflow for local display, BAS integration, or both. Measurement technologies include:

- Averaging differential pressure devices, which sample total and static pressure at multiple points and infer airflow using the resulting differential pressure, duct area, and applicable device coefficient. These devices may be installed as standalone duct stations or integrated into terminal unit inlets, fan systems, or other equipment.
- Thermal dispersion devices, which use heated and reference-sensing elements to infer airflow from convective heat transfer in the airstream.

Other approved measurement technologies may also be used. Device selection should account for the measurement location, duct geometry, available straight-run length, expected airflow range, minimum airflow to be measured, air density, temperature, contamination potential, maintenance access, and manufacturer installation requirements.

Common Test Methods

The appropriate airflow testing method depends on the measurement location, terminal geometry, expected airflow range, accessibility, flow profile, and required accuracy. Common instruments include:

- **Capture hood (also referred to as a flow hood or balometer):** Commonly used to measure airflow at compatible supply diffusers and return or exhaust grilles. The hood should fully encompass the terminal, maintain an appropriate seal, and operate within its calibrated range. Hood-induced resistance, terminal geometry, non-uniform flow, and low airflow may affect results. Instrument- or terminal-specific correction factors should be applied where required by the testing procedure
- **Velocity grid:** Measures air velocity at multiple sensing locations across a grille, filter, diffuser, or other opening. Airflow is determined using the measured velocity, the effective area appropriate to the measurement requirement, and any required correction factors. A velocity grid may be useful where a capture hood will not fit, but results depend on proper positioning and flow direction and uniformity.
- **Thermal or hot-wire anemometer:** Measures air velocity and may be used for multiple duct traverses, diffuser or grille measurements, and fume hood face-velocity testing. It may also be useful where a capture hood will not fit. The testing procedure should address probe orientation, turbulence,

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temperature effects, contamination, and sufficient sampling across the measurement area to obtain a representative result. A single spot reading may not represent airflow across the entire opening.

- **Pitot static tube:** Samples total and static pressure during a duct traverse. A calibrated differential pressure instrument measures the difference, known as velocity pressure. Air velocity and airflow are determined using the traverse readings, duct area, air density, and applicable correction factors are known.

When checking an installed airflow device, its indicated value should be compared with an independent reference measurement under the same stable operating conditions. Both values must represent the same airflow. For example, a duct station serving several terminals should be compared with their combined airflow, rather than a reading at only one terminal. Differences caused by duct leakage, intervening branches, or equipment must be identified and accounted for during commissioning and testing, adjusting, and balancing (TAB).

Verification and Ongoing Performance Testing

Verification determines whether an installed airflow indication meets defined acceptance criteria when compared with an independent reference measurement. It differs from calibration, which establishes the relationship between indicated reference values, including measurement uncertainty, and adjustment, which changes a device or system parameter. TAB addresses system airflow and distribution to achieve specified performance.

Installed airflow indications can become inaccurate because of contamination, sensing element degradation, transmitter drift, configuration changes, or altered flow conditions. A recurring verification program should establish test intervals based on risk, system criticality, manufacturer recommendations, observed performance, and applicable facility standards.

Before testing, qualified personnel should identify the applicable acceptance criteria and select a suitable reference method from those described in the preceding section or an appropriate manufacturer-specified procedure. Acceptance criteria should be established by the governing project or facility documents and account for measurement uncertainty, operating conditions, and system effects. Personnel must then record the as-found BAS-displayed airflow value and obtain an independent reference measurement under stable, documented operating conditions. The values must be compared using the established acceptance criteria. If the difference exceeds the acceptance limit, the cause must be investigated before adjustment.

Corrective action may include cleaning or repairing sensing elements, correcting installation or configuration problems, or adjusting a manufacturer-approved calibration parameter. Adjustments to a K-factor or other conversion coefficient must follow the manufacturer's procedure. Following corrective action, verification must be repeated and the as-found condition, corrective action, and as-left result must be documented.

Conclusion

Reliable airflow measurement supports ventilation control, room pressure relationships, and energy-efficient HVAC operation in laboratories and APFs. BAS-displayed values should be periodically verified using suitable reference instruments, documented procedures, and defined acceptance criteria. Discrepancies must be investigated, with corrective action, calibration, or TAB performed as warranted. Together, these activities help maintain reliable airflow data and support continued system performance.

Resources

1. NIH Design Requirements Manual
2. ANSI/ASHRAE Standard 111-2024, Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation and Air-Conditioning Systems
3. ANSI/ASHRAE Standard 41.2-2026, Standard Methods for Air Velocity and Airflow Measurement, where its scope is applicable. ASHRAE currently identifies the 2026 edition on its standards page.
4. NIST, Policy on Metrological Traceability and associated frequently asked questions.
5. The applicable NEBB, AABC, or project-specified TAB procedural standard. NEBB released the Tenth Edition of its TAB procedural standard in September 2026; cite the edition consulted, which may be an earlier edition if that was the source used during drafting.
6. Current installation, commissioning, calibration, and operating manuals for the actual airflow stations, terminal devices, control valves, capture hoods, velocity grids, thermal anemometers, and Pitot instruments discussed.
7. Applicable facility SOPs, commissioning plans, calibration procedures, or approved test plans establishing acceptance tolerances and recurring verification frequency.
8. The applicable fume-hood test standard or facility procedure, if fume-hood face-velocity testing remains as an example.