ARE WE USING ACH CORRECTLY?

Diagnostic Guide
GD-017

A technical diagnostic guide to air changes per hour, airflow function, pressure control, and ventilation design in containment laboratories

A practical guide to determining when ACH is a useful derived metric, when it becomes a misleading design shortcut, and what should actually drive ventilation decisions.

DIAGNOSTIC GUIDE

HOW TO USE THIS GUIDE

ACH IS A RESULT OF AIRFLOW AND ROOM VOLUME. IT IS NOT THE CONTAINMENT STRATEGY.

This guide was created for projects and operating laboratories where a single ACH target has become the dominant ventilation requirement without a clear explanation of what problem that number is intended to solve.

Why we developed it

Air changes per hour are easy to understand and compare. This makes ACH useful for describing ventilation intensity, but it also makes the metric easy to extend beyond its proper role and turn into a universal design criterion.

Containment airflow may perform several functions: maintaining directional airflow and pressure relationships, supporting dilution, removing heat, serving equipment exhaust, restoring conditions after disturbances, or meeting applicable facility criteria. Those functions do not necessarily produce the same airflow requirement.

The purpose of this guide is to help technical teams begin with the required function, calculate the airflow needed to achieve it, and only then use ACH as a descriptor of the resulting condition rather than as an automatic starting point.

Who can use it

The guide is intended for HVAC engineers, architects, biosafety personnel, commissioning teams, facility managers, and project teams involved in the design or review of ventilation for high-containment laboratories.

It may also be used retrospectively when an operating facility is considering reducing airflow, optimizing energy use, or correcting a design inherited from high ACH targets.

HOW TO USE IT IN PRACTICE

Identify every reason the room needs airflow. Determine the airflow associated with pressure control, thermal load, dilution, equipment, and operational recovery. Compare those requirements, identify the governing case, and only then calculate the resulting ACH.

The objective is not to eliminate ACH. It is to place it in the correct position within the design logic.

01 DEFINE

02 CALCULATE

03 COMPARE

04 VERIFY

HOW THIS GUIDE MAY BE USED — AND WHAT IT DOES NOT AUTHORIZE

This guide is a general diagnostic-orientation tool. It is designed to help structure technical questions, organize evidence, and define what requires more specific evaluation.

Acceptable use

It may be used to:

- structure preliminary technical investigations;
- prepare internal reviews and multidisciplinary discussions;
- identify missing information, measurements, and documentation;
- support definition of the scope of a subsequent evaluation;
- serve as educational and internal technical reference material.

It does not constitute

This guide does not establish a universal ACH requirement and does not constitute a ventilation design, site-specific airflow calculation, acceptance criterion, certification, compliance determination, authorization to modify or operate, or a site-specific recommendation.

Technical and operational decisions

No decision regarding increasing or reducing airflow, selecting an ACH target, modifying setpoints, energy optimization, continued operation, or return to service should be based solely on this guide.

Applicable technical basis

The content should be interpreted together with the risk assessment, intended room function, thermal and process loads, pressure-control strategy, ventilation calculations, applicable standards and requirements, commissioning criteria, and other site-specific documentation.

Competent personnel

Airflow and ventilation changes that may affect pressure, directional airflow, thermal performance, equipment, or recovery should be designed and verified by appropriately qualified personnel.

Responsibility

BioLab Solutions assumes no responsibility for decisions, modifications, interventions, or actions carried out outside a site-specific evaluation and without review by competent personnel.

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01 Understand what ACH actually measures

ACH is a volumetric air-change rate, not a direct measure of containment. The project should also state whether the value is calculated from supply airflow, exhaust airflow, or another explicitly defined basis.

Air changes per hour describe how many equivalent room volumes are supplied or exhausted during one hour.

Conceptually

ACH = hourly airflow ÷ room volume

A small room and a large room receiving the same CFM will have different ACH values. Conversely, two rooms with the same ACH may require very different quantities of air.

ACH does not directly indicate

- room differential pressure;
- directional airflow;
- air-distribution effectiveness;
- HEPA integrity;
- envelope leakage;
- fan reserve;
- recovery after door opening.

ACH DESCRIBES VENTILATION INTENSITY. BY ITSELF, IT DOES NOT DESCRIBE CONTAINMENT PERFORMANCE.

02 Begin with the function the airflow must perform

Different airflow functions generate different design quantities.

Airflow function	Question that should be answered
Pressure / directional airflow	What relationship between supply and exhaust is required to maintain the intended cascade across the actual envelope?
Thermal control	What airflow is needed to remove sensible heat from equipment, lighting, and occupants?
Dilution	What ventilation rate is justified by the contaminant-generation scenario and risk basis?
Equipment exhaust	What airflow is removed by BSCs, process exhaust, or other directly connected equipment?
Recovery	How quickly must the room return to an accepted condition after a disturbance or process event?
Environmental control	What temperature/humidity performance must the ventilation system support?

Design logic: determine the airflow associated with each relevant function, reconcile their interactions within the room balance, and identify the governing condition or combination of conditions. Then review the resulting ACH.

03 Do not use ACH as a substitute for pressure design

Pressure depends on airflow offset and envelope leakage, not only on total room air change.

Two rooms can operate at the same ACH and exhibit very different pressure behavior.

Supply-exhaust offset

Directional airflow depends on the relationship between supply, exhaust, and leakage/transfer air.

Envelope leakage

A leakier room may require a larger exhaust offset to maintain the same pressure.

Reference space

Pressure only has meaning relative to another defined space.

Door behavior

Open doors temporarily dominate the pressure condition regardless of nominal ACH.

Control authority

Fans and terminals must have sufficient range to maintain the offset dynamically.

Adjacent zones

Changes in shared systems may alter the cascade even when room ACH remains unchanged.

A ROOM DOES NOT BECOME CONTAINED BECAUSE IT HAS “ENOUGH ACH.”

04 Separate dilution from air change

Room-volume turnover does not mean perfect mixing or uniform contaminant removal.

Actual dilution depends on

- source location;
- supply-air distribution;
- exhaust location;
- mixing;
- equipment obstruction;
- room geometry;
- thermal plumes;
- contaminant behavior.

ACH does not guarantee mixing

Increasing total airflow may improve dilution under some conditions, but poor distribution can still leave local zones with low removal or create short-circuiting between supply and exhaust.

Where dilution performance matters, evaluate the actual airflow pattern and source scenario rather than relying only on nominal room air change.

AIR CHANGES COUNT VOLUME. THEY DO NOT DESCRIBE WHERE THE AIR GOES.

05 Determine whether thermal load is actually the governing airflow requirement

Modern laboratory equipment can make thermal control more demanding than nominal airflow associated with biosafety.

A room may need more air because of heat, not because containment requires a higher ACH.

Equipment heat

Analyzers, freezers, incubators, centrifuges, and electronics can generate significant sensible heat loads.

Lighting / occupants

These loads may be modest individually but still contribute to total room cooling demand.

Supply-air temperature

The colder the supply air is relative to the room setpoint, the more sensible heat each CFM can remove.

Pressure consequence

Increasing supply for cooling may require additional exhaust to preserve the intended negative relationship.

Local cooling option

An independent cooling system may reduce ventilation demand but should be evaluated for airflow disturbance and maintainability.

Future load

Equipment additions can change the governing airflow long after the original laboratory has been commissioned.

> Do not attribute a high airflow requirement to “BSL-3” if the actual driver is thermal load.

06 Consider equipment exhaust separately

Direct exhaust can dominate the room balance without appearing as a simple ACH requirement.

Examples

- ducted BSCs;
- chemical fume hoods;
- local capture systems;
- process exhaust;
- equipment cooling exhaust;
- autoclave canopy or other local systems where used.

Room-balance consequence

Equipment exhaust forms part of the room's total exhaust balance. If it cycles on and off, the pressure strategy must accommodate those operating states.

A fixed ACH target can conceal the fact that the air system must respond dynamically to equipment status.

PROCESS EXHAUST IS NOT “EXTRA ACH.” IT IS A SPECIFIC AIRFLOW LOAD THAT MUST BE INTEGRATED INTO THE ROOM BALANCE.

WHEN ACH BECOMES MISLEADING

COMMON DESIGN SHORTCUTS

“BSL-3 means X ACH.”

A containment level does not automatically define a universal ventilation rate for every facility and activity.

“More ACH is always safer.”

Higher airflow can increase energy use, noise, turbulence, filter loading, and control difficulty without necessarily improving the relevant containment function.

“Same ACH means same performance.”

Room size, geometry, leakage, equipment, and air distribution can make identical ACH values behave very differently.

“ACH demonstrates dilution.”

Nominal air change does not demonstrate local removal or effective mixing.

“ACH determines pressure.”

Pressure depends on the offset between supply and exhaust, leakage, and control response, not only on total air change.

“The historical number must be preserved forever.”

Inherited values should be reviewed against current risk, equipment, envelope condition, and system performance before being treated as immutable.

A CONVENIENT NUMBER SHOULD NOT SUBSTITUTE FOR A TECHNICAL EXPLANATION.

07 Use ACH carefully in recovery calculations

Higher air-change rates can shorten theoretical clearance time, but the model depends on assumptions.

Theoretical air-clearance relationships generally assume ideal or sufficiently effective mixing, a defined initial concentration, and that contaminant generation has ceased during the recovery period being considered.

Before using a recovery calculation, define

- which contaminant or event is being considered;
- the initial condition;
- the target condition;
- whether the mixing assumptions are reasonable;
- whether source generation has ceased;
- how the result will be operationally verified.

Do not confuse theoretical clearance with room safety

Calculated air change is one input. Actual recovery may be affected by poor mixing, surface deposition, continued release, local dead zones, or equipment geometry.

Where recovery time is operationally critical, validate the basis rather than treating the formula as self-sufficient.

RECOVERY TIME IS A PERFORMANCE QUESTION. ACH IS ONE VARIABLE IN THE RESPONSE.

EVERY UNJUSTIFIED AIR CHANGE HAS A LIFECYCLE COST

High-containment ventilation is energy intensive because the air being moved typically must be conditioned, filtered, and exhausted continuously.

Fan energy

Higher airflow increases fan power and often increases system pressure demand.

Cooling

More outdoor or replacement air increases sensible and latent conditioning loads.

Heating / reheat

High ventilation rates can substantially increase heating and reheat demand.

Filter loading

Higher airflow can accelerate loading and increase resistance over the lifecycle.

Equipment sizing

High inherited ACH values can drive larger AHUs, ductwork, exhaust fans, and backup systems.

Operational rigidity

A system designed around excessive airflow may have limited flexibility for reduced modes or later optimization.

> Energy optimization should remove unjustified airflow without weakening the functions that airflow was actually performing.

08 Review inherited ACH values before treating them as design intent

Some ventilation rates persist because they were repeated, not because their original justification remains visible.

Trace the origin

- risk assessment;
- Basis of Design;
- standard or institutional criterion;
- thermal calculation;
- process-exhaust requirement;
- commissioning record;
- historical project convention.

If the basis cannot be found

Do not assume the value is wrong, but do not treat it as technically self-justifying either.

Reconstruct the room's actual airflow functions and determine whether the current rate is still necessary.

A NUMBER WITHOUT A VISIBLE FUNCTION IS A WEAK BASIS FOR LIFECYCLE DECISIONS.

IF REDUCING AIRFLOW IS BEING CONSIDERED

REDUCE AIRFLOW ONLY AFTER DEFINING WHAT IT MUST CONTINUE TO DO

Pressure stability

Confirm that reduced airflow still maintains the accepted cascade under normal conditions.

Directional airflow

Verify movement across critical boundaries and representative door-opening events.

Thermal performance

Ensure room temperature remains acceptable under realistic equipment loads.

Equipment integration

Confirm that BSC/process-exhaust states remain compatible with the room balance.

Recovery

Evaluate relevant recovery criteria where they form part of the operational basis.

Controls / alarms

Retune setpoints or control loops where required and functionally verify the new condition.

Change-control point: a material airflow reduction modifies the accepted operating condition and should be documented and reverified accordingly.

DEFINE THE DENOMINATOR AND AIRFLOW BASIS

“12 ACH” IS INCOMPLETE IF THE PROJECT DOES NOT STATE WHICH AIRFLOW AND WHICH ROOM VOLUME IT USES

In a negatively pressurized room, supply and exhaust airflows are intentionally different. Either can be converted to ACH, but they do not describe the same quantity.

Supply ACH

Describes mechanically supplied air relative to room volume. It may be relevant to thermal conditioning or ventilation delivery.

Exhaust ACH

Describes mechanically exhausted air relative to room volume. It may be higher than supply ACH when transfer air supports the negative-pressure strategy.

Room volume

Define the actual volume used in the calculation and apply it consistently. Ceiling configuration, soffits, or other geometry can produce apparently different ACH values from the same airflow.

Functional requirement

The governing airflow should still be derived from pressure, thermal load, equipment exhaust, dilution, recovery, or another defined requirement. ACH is the resulting normalized metric.

Diagnostic rule: never compare ACH values between rooms, projects, or verification reports until the airflow basis and room-volume convention are known.

DIAGNOSTIC SEQUENCE

ARE WE USING ACH CORRECTLY?

01

Can we state what function the room airflow must perform?

No → do not begin with an ACH target; first define pressure, thermal-load, dilution, equipment, and recovery needs.
Yes → continue.

02

Has the airflow been calculated for each relevant function?

No → calculate the functional requirements before selecting the governing airflow.
Yes → continue.

03

Is the resulting ACH being used as a descriptor rather than as the sole evidence of performance?

No → reconnect the number to the underlying functions.
Yes → continue.

04

Does the selected airflow create unintended pressure, energy, or control problems?

Yes → revisit the governing requirement and system design.
No → continue.

05

Can inherited ACH values be traced to a current technical basis?

No → reconstruct and review before automatically changing or retaining them.
Yes → continue.

06

Has the final airflow condition been functionally verified?

No → the number remains a design assumption.
Yes → retain the verified airflow and its justification as part of the technical baseline.

ACH REVIEW PACKAGE

WHAT SHOULD BE AVAILABLE?

Room basis

- room volume;
- hazard/activity;
- occupancy;
- equipment;
- temperature/RH criteria;
- pressure relationship.

Airflow functions

- pressure offset;
- thermal load;
- dilution basis;
- equipment exhaust;
- recovery requirement;
- applicable criteria.

System evidence

- supply/exhaust CFM;
- calculated ACH;
- fan capacity;
- damper position;
- filter DP;
- air-distribution arrangement.

Verification

- TAB;
- pressure testing;
- recovery after door opening;
- temperature trends;
- controls functional testing;
- final accepted condition.

Review objective: make every significant airflow traceable to a defined function rather than to a stand-alone ACH convention.

KEEP THE METRIC, BUT USE IT FOR THE RIGHT PURPOSE

ACH remains a useful engineering and operational metric when its role is clear.

Useful applications

- comparing ventilation intensity between rooms;
- documenting the resulting design condition;
- supporting selected recovery calculations;
- tracking significant airflow changes;
- communicating ventilation rates to operators;
- comparing energy intensity.

Keep the hierarchy clear

Function first.
What must the airflow achieve?

Then airflow.
How much air is required?

Finally, ACH.
What room air-change rate results?

ACH IS MOST USEFUL AFTER THE ENGINEERING QUESTION HAS BEEN ANSWERED.

BEFORE ACCEPTING OR CHANGING AN ACH TARGET, DEFINE WHAT FUNCTION THE AIRFLOW MUST PERFORM

Use this checklist as diagnostic support. A checked item does not constitute acceptance; each element must be interpreted against the risk basis, facility configuration, and applicable criteria.

□ State whether the cited ACH is based on supply airflow, exhaust airflow, or another explicitly defined basis.

□ Confirm the room volume used in the calculation and that the same convention is used when comparing values.

□ Identify the actual functions governing airflow: pressure relationship, heat removal, equipment exhaust, dilution, recovery, or another requirement.

□ Determine the airflow required for each governing function before converting the result to ACH.

□ Review whether exhaust ACH exceeds supply ACH because intentional transfer air supports the pressure relationship.

□ Do not infer containment quality, air-distribution quality, or recovery performance from ACH alone.

□ Review whether an inherited ACH target is driving unnecessary airflow when another functional requirement is the actual governing condition.

□ Before reducing airflow, confirm available control margin, pressure stability, thermal performance, and equipment-exhaust needs.

□ After any airflow change, verify the affected containment functions rather than confirming only the new ACH value.

□ Document the airflow basis, room volume, governing requirement, and verification evidence whenever ACH is used as an acceptance or operating descriptor.

Technical-use note: This review checklist is a diagnostic-support tool. It does not establish site-specific acceptance criteria, replace risk assessment or professional judgment, constitute certification, or authorize operation or return to service.

If the review identifies a condition requiring site-specific evaluation, BioLab Solutions can support technical assessment, verification, and definition of the required evidence.

RELATED BIOLAB RESOURCES

EXPLORE AIRFLOW, PRESSURE, ENERGY, AND FUNCTIONAL VERIFICATION IN GREATER DEPTH

NT-010
Directional airflow as control logic

NT-011
Pressure cascades as dynamic state conditions

NT-012
ACH as a derived variable

NT-013–017
Pressure-control failure modes, HVAC integration, exhaust authority, redundancy, and control hierarchy

NT-039
Lifecycle drift in containment systems

NT-045–048
Sustainability, energy recovery, and lifecycle energy demand

GD-004
Why does this high-containment laboratory use so much energy?

GD-011
Why is this room so difficult to balance?

BIOLAB DIAGNOSTIC GUIDES

Short technical resources organized around real containment problems rather than individual disciplines.

Series concept: symptom → system → evidence → restoration.

CLOSING DIAGNOSTIC PRINCIPLE

DESIGN THE AIRFLOW. THEN CALCULATE THE ACH.

ACH is useful precisely because it simplifies airflow into a room-scale metric. The simplification becomes problematic when the metric is asked to replace the engineering logic beneath it.

Containment laboratories need airflow for specific reasons: pressure control, directional airflow, heat removal, dilution, process exhaust, and recovery. Those requirements should be explicit and technically justified.

Once airflow has been defined and verified, ACH becomes an informative descriptor of the operating condition. Used in that order, the number helps communicate performance without substituting for it.

BIOLAB SOLUTIONS

Independent technical support for planning, design, commissioning, assessment, and lifecycle management of high-containment laboratories.

For site-specific evaluation, BioLab Solutions can support technical review, verification, and definition of evidence requirements.

FUNCTION → AIRFLOW REQUIREMENT → ACH → VERIFICATION