WHY IS THE PRESSURE IN MY BSL-3 UNSTABLE?

Diagnostic Guide
GD-001

A technical diagnostic guide to pressure relationships, airflow control and containment boundaries

A practical field-oriented guide for diagnosing recurring pressure alarms, unstable cascades and changes in BSL-3 airflow performance.

DIAGNOSTIC GUIDE

HOW TO USE THIS GUIDE

START WITH THE SYMPTOM. DO NOT STOP AT THE NUMBER.

This guide was created for a common containment problem: a BSL-3 room or pressure cascade that no longer behaves as expected, with no obvious single cause.

Why we created it

Pressure instability is often approached as a local HVAC fault. That can lead directly to airflow adjustment, setpoint changes or rebalancing before the underlying condition has been established.

In practice, the pressure reading sits at the intersection of several systems: the containment boundary, supply and exhaust airflow, controls, filtration, doors, adjacent spaces, instrumentation, maintenance history and operating conditions.

The purpose of this guide is to provide a disciplined diagnostic sequence that helps technical teams move from the visible symptom to the system dependency that has changed.

Who can use it

The guide is intended for facility managers, biosafety personnel, engineers, commissioning teams, maintenance staff and institutional decision-makers involved in the operation or evaluation of high-containment laboratories.

It is not a commissioning protocol or a substitute for project-specific procedures. It is a structured troubleshooting aid that helps organize what should be checked, measured, compared and escalated.

HOW TO USE IT IN PRACTICE

Begin with the observed condition. Confirm that the deviation is real. Review what changed. Then move through boundary condition, exhaust authority, supply behavior, cascade stability and disturbance response.

Use the symptom matrix to narrow likely causes, the evidence checklist to assemble a useful diagnostic record, and the decision sequence to determine when a local maintenance issue has become a containment deviation requiring broader technical review.

The objective is not to prescribe one universal fix. It is to help establish the cause before corrective action changes the system again.

01	02	03	04
CONFIRM	TRACE	TEST	RESTORE

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

This guide is a general diagnostic guidance tool. It is designed to help structure technical questions, organize evidence and define what requires a 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 material and an internal technical reference.

Does not constitute

This guide does not constitute a design, specification, operating procedure, commissioning protocol, acceptance criterion, certification, compliance determination, operating authorization or site-specific recommendation for any particular facility.

Technical and operational decisions

No corrective action, setpoint modification, airflow change, intervention on critical systems, return-to-service decision or operational decision should be based solely on this guide.

Applicable technical basis

The content should be interpreted together with the risk assessment, Basis of Design, commissioning evidence, approved operating criteria, regulatory requirements, manufacturer instructions, institutional procedures and other site-specific documentation.

Competent personnel

Investigation, intervention, adjustment and restoration of containment-critical functions should be performed or reviewed by appropriately qualified personnel, with a level of verification proportionate to the function affected.

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.

01 What the pressure reading actually tells you

Pressure is a relationship between reference points, not a complete proof of containment.

A differential pressure value is meaningful only when the boundary, airflow path and reference condition are understood.

If a laboratory is maintained at −30 Pa relative to an adjacent anteroom, the instrument is reporting that pressure relationship. It does not independently demonstrate the integrity of the containment boundary, airflow direction through every opening, exhaust filtration integrity, available exhaust capacity, stability of the complete cascade or behavior during disturbance.

A normal reading can coexist with a changed system

Increased envelope leakage may be compensated by additional exhaust airflow. The pressure value remains acceptable, but the system may require greater fan authority and retain less capacity to respond when a door opens or a filter becomes loaded.

A pressure transmitter can also display a plausible value while its reference tubing, calibration, location or zero condition has changed.

Interpret pressure as an indicator

Pressure is an important containment indicator, but it must be interpreted as part of the complete airflow and boundary system.

The objective is to determine whether the current pressure value still represents the same system condition that was previously accepted.

THE NUMBER IS AN OUTCOME. THE SYSTEM THAT PRODUCES IT IS THE DIAGNOSTIC OBJECT.

02 Confirm that the deviation is real

Do not change airflow quantities or control parameters until the reported condition has been independently verified.

Independent measurement

Verify differential pressure using an independent calibrated instrument and compare it with:

- installed room monitor;
- BMS value;
- independent measurement.

Any significant discrepancy should be resolved before mechanical adjustments are made.

Measurement system

- sensor calibration;
- zero condition;
- pressure tubing;
- reference port condition;
- reference location;
- tubing obstruction or disconnection;
- instrument range and resolution;
- signal damping or averaging;
- BMS/controller scan frequency and trend sampling interval.

Trend behavior

Determine whether the deviation is:

- continuous or intermittent;
- gradually worsening;
- associated with door operation;
- linked to equipment or another HVAC zone;
- recent following maintenance or modification.

Reference condition

The reference point matters. A room pressure reading has meaning only in relation to the space or reference against which it is measured.

A sensor problem should not be “corrected” by increasing airflow.

> **First rule:** confirm the condition before modifying the system that produces it.

03 Ask what changed

A previously stable system that becomes unstable has usually experienced some change, even when that change was gradual.

Mechanical

- HEPA filter replacement or loading
- fan maintenance
- belt or motor replacement
- VFD adjustment
- damper adjustment
- duct modification
- new branch connection
- rebalancing of another room

Controls

- pressure setpoint change
- alarm threshold change
- PID/control-loop adjustment
- sensor recalibration
- interlock modification
- software or BMS update
- normal/failure sequence change

Architectural

- door replacement
- door closer adjustment
- gasket replacement
- new penetration
- ceiling or service work
- wall modification
- pass-through or equipment installation

Operational

- new equipment
- increased equipment heat load
- higher occupancy
- increased frequency of door opening
- new procedures
- change in work schedule
- change in access pattern
- changes in overall building HVAC operation
- effects of schedule, wind or stack effect on adjacent or reference spaces

IF THE SYSTEM WAS STABLE, CHANGE HISTORY IS PART OF THE DIAGNOSTIC RECORD.

04 Confirm the containment boundary

Pressure cannot be interpreted independently of leakage.

The exhaust system establishes negative pressure by removing more air than is mechanically supplied. The difference enters through leakage pathways.

Inspect the interfaces

- door seals and frames;
- floor/wall and ceiling interfaces;
- electrical, pipe and duct penetrations;
- pass-through and autoclave interfaces;
- glazing and panel joints where applicable;
- recently repaired or modified openings.

Some leakage is inherent in real buildings. The question is whether it occurs through the intended boundary and remains within the assumptions used to size and control the system.

THE COMPENSATION PROBLEM

Increasing exhaust airflow can restore a pressure reading even when leakage has increased.

That can increase energy use, filter loading and fan demand while reducing available response margin.

If the room now needs substantially more exhaust to maintain the same differential, establish why.

05 Evaluate exhaust authority

The question is not whether the fan is running. It is whether the exhaust system still has enough authority to control the room.

In negative-pressure containment, exhaust capacity is central to pressure control.

Review

- measured exhaust airflow;
- commissioned exhaust airflow;
- fan speed and VFD output;
- damper position;
- available fan capacity;
- filter differential pressure;
- duct resistance;
- fan condition;
- redundancy state;
- control response.

Available margin matters

A system operating continuously near maximum fan speed has little remaining authority to compensate for increasing filter resistance, leakage or disturbance.

HEPA loading

Where exhaust HEPA filtration is used, examine filter differential pressure together with fan speed, airflow, room pressure and available capacity.

CONTROL AUTHORITY IS THE CAPACITY TO PRESERVE THE REQUIRED RELATIONSHIP WHEN CONDITIONS CHANGE.

06 Evaluate supply behavior and control interaction

Supply is reviewed in relation to the exhaust strategy, not as an independent target.

Check supply conditions

- actual supply airflow;
- commissioned supply airflow;
- damper position;
- VAV/control response where applicable;
- supply fan condition;
- interaction with adjacent rooms;
- changes elsewhere in the air-handling system.

Changing one zone can redistribute available air and alter pressure relationships elsewhere in the system.

Look for control-loop instability

Pressure instability can result from supply and exhaust controls repeatedly correcting against one another.

- oscillating room pressure;
- damper hunting;
- repeated fan-speed changes;
- alternating high/low alarms;
- slow recovery after door movement.

The correct intervention may be control sequencing rather than increased airflow.

> A pressure loop should be evaluated as part of the complete air-control hierarchy, especially where supply and exhaust systems share common fans or control logic.

07 Diagnose the cascade, not only the affected room

A BSL-3 pressure relationship exists within a sequence of spaces.

Evaluating only the room showing the alarm may overlook a change originating in an adjacent zone.

ILLUSTRATIVE CASCADE

GENERAL CORRIDOR → ANTEROOM → BSL-3 LABORATORY

0 Pa → −15 Pa → −30 Pa

Values are illustrative only. Project-specific criteria govern.

Verify each relationship

- corridor to anteroom;
- anteroom to laboratory;
- laboratory to adjacent higher-risk spaces;
- relevant support spaces;
- response during door operation;
- airflow visualization at critical openings, where appropriate.

Why adjacent zones matter

If an anteroom becomes more negative, the differential between the anteroom and laboratory may decrease even though nothing inside the laboratory has changed.

For that reason, the diagnostic object is the cascade, not only the room presenting the alarm.

08 Observe door behavior and recovery

Doors are transient openings in the containment boundary.

Pressure disturbance during door opening is expected. The issue is whether the system responds within the performance criteria established for the facility.

Observe

- magnitude of pressure loss;
- directional airflow during opening;
- recovery after closure;
- interaction with interlocked doors;
- effect of rapid sequential openings;
- which door opens and the approximate duration of opening;
- behavior of interlocked or sequential doors;
- door closer performance;
- gasket condition.

Operational resilience

A room that meets its setpoint only when all doors remain undisturbed may not have sufficient resilience for its actual operating pattern.

Repeated alarms associated with door operation may also indicate that operating conditions have moved beyond the assumptions used during design or commissioning.

SYMPTOM MATRIX

WHAT THE PATTERN MAY BE TELLING YOU

Observed condition	Possible causes
Pressure gradually deteriorates over weeks or months	Filter loading, fan degradation, increasing leakage, sensor drift
Pressure drops substantially whenever the door opens	Insufficient exhaust reserve, high leakage, slow control response, changed door behavior
Pressure repeatedly oscillates around the setpoint	Control-loop instability, supply/exhaust interaction, damper hunting
Pressure appears correct, but airflow direction is questionable	Incorrect pressure reference, sensor error, local leakage pathway, cascade problem
One room becomes unstable after another room is rebalanced	Shared-system interaction, airflow redistribution, reduced available fan capacity
Alarm begins immediately after maintenance	Changed damper position, sensor issue, filter replacement, door adjustment, undocumented setpoint change
Fan operates continuously near maximum speed	Increasing system resistance, excessive leakage, insufficient capacity or altered operating condition
Pressure is stable under normal conditions but fails during a disturbance	Limited system resilience, transition-performance issue, control-response limitation
Multiple rooms become unstable simultaneously	Central exhaust/supply problem, common reference problem, control failure or utility disturbance
Pressure changes according to time of day or weather conditions	Building pressure change, HVAC scheduling, stack effect, wind influence or operation of adjacent zones
BMS trend appears unstable, but independent measurement is comparatively stable	Sensor damping, trend sampling, controller response, reference tubing or signal/configuration problem

> These are diagnostic starting points, not conclusions. Confirm by measurement.

BEFORE CORRECTIVE ACTION

WHAT NOT TO DO FIRST

Do not automatically increase ACH

More airflow does not inherently create better containment and can increase energy, noise, filter loading and control sensitivity.

Do not increase exhaust blindly

If the room was stable at a lower airflow, determine why more exhaust is now required.

Do not change alarm limits to silence alarms

First determine whether the alarm reflects instrumentation error, poor configuration or actual system instability.

Do not widen pressure tolerances retrospectively

Acceptance criteria should reflect the containment strategy and demonstrated performance, not a deteriorating system.

Do not rebalance only the affected room

Rooms connected to a common air system interact. A local correction can transfer the problem elsewhere.

Do not treat a normal display as proof of restoration

Corrective work should be followed by verification appropriate to the function that was changed.

SUPPRESSING THE SYMPTOM IS NOT THE SAME AS RESTORING THE CONTAINMENT CONDITION.

ESCALATION

WHEN DOES PRESSURE INSTABILITY BECOME A CONTAINMENT DEVIATION?

Not every transient event represents containment failure. Escalation is required when the operating condition on which containment depends can no longer be reliably demonstrated.

Examples

- directional airflow cannot be demonstrated;
- the intended pressure hierarchy is repeatedly lost;
- the room cannot maintain its defined operating range;
- recovery after normal disturbance is unacceptable;
- pressure alarms are routinely overridden or ignored;
- exhaust capacity is at or near its limit;
- increasing airflow is required to compensate for boundary deterioration;
- a containment-critical intervention has not been followed by appropriate verification.

Change the management category

At this point the problem should be managed as a containment condition, not merely as an HVAC comfort or maintenance issue.

Operational restrictions may be appropriate until the affected function is understood and restored.

FIELD EVIDENCE

WHAT TO COLLECT BEFORE CORRECTIVE ACTION

Pressure

- current differentials
- independent verification
- cascade measurements
- BMS trends
- alarm history

Airflow

- supply CFM
- exhaust CFM
- baseline values
- fan speed
- damper positions
- VFD output

Filtration

- HEPA differential pressure
- integrity-test status
- replacement history
- housing/seal work

Boundary

- door condition
- gaskets
- penetrations
- observed leakage
- recent construction/service work

Controls

- setpoints
- alarm thresholds
- control sequences
- programming changes
- sensor calibration

Baseline

- commissioning results
- TAB reports
- functional tests
- design pressure criteria
- design airflow
- as-builts

Diagnostic objective: compare the current condition with a known accepted condition rather than diagnose the system from isolated present-day readings.

DIAGNOSTIC SEQUENCE

A PRACTICAL ORDER OF REVIEW

01

Independent measurement confirms the deviation?

No → investigate sensor, reference, calibration, tubing or BMS representation.

Yes → continue.

02

Recent maintenance, operational or configuration change?

Yes → identify the affected function and compare pre-/post-intervention conditions.

No or unknown → continue.

03

Containment boundary in expected condition?

No → correct the boundary/interface defect and reassess airflow requirements.

Yes → continue.

04

Exhaust capacity and control authority adequate?

No → investigate fan condition, filters, duct resistance, dampers, redundancy and available capacity.

Yes → continue.

05

Supply and exhaust controls stable and correctly sequenced?

No → review balancing and control logic.

Yes → continue.

06

Full cascade stable under normal disturbances?

No → conduct integrated functional evaluation.

Yes → investigate intermittent operational conditions and less obvious system interactions.

RESTORATION SHOULD BE DEMONSTRATED

Corrective work should not end when the pressure monitor returns to its expected value.

Pressure sensor intervention

- calibration confirmation;
- independent pressure comparison;
- alarm verification.

Door intervention

- closure verification;
- observation of pressure recovery;
- confirmation of directional airflow.

Airflow rebalance

- supply/exhaust measurement;
- cascade verification;
- alarm testing;
- disturbance/recovery testing.

HEPA replacement

- applicable integrity testing;
- airflow confirmation;
- pressure-cascade verification.

Control sequence / BMS intervention

- confirmation of the approved sequence;
- verification of setpoints and alarm thresholds;
- testing under normal and disturbed conditions;
- recovery and cascade verification;
- updated configuration record.

> A significant change to controls or mechanical systems may require partial recommissioning. The level of verification should correspond to the containment function that was modified.

> **THE OBJECTIVE IS TO DEMONSTRATE RESTORATION, NOT ASSUME IT BECAUSE THE ORIGINAL SYMPTOM DISAPPEARED.**

BEFORE ADJUSTING SETPOINTS OR "CORRECTING" PRESSURE

Use this checklist as a review filter. A checked item does not constitute acceptance; each item must be interpreted against the risk basis, site configuration and applicable criteria.

□ Characterize the symptom: when it occurs, duration, frequency, affected spaces and whether there is a repeatable triggering condition.

□ Compare the BMS reading with an appropriate independent measurement when the condition warrants it.

□ Confirm the pressure reference point and that the reference has not changed or been affected by another zone.

□ Compare supply and exhaust airflow with the accepted baseline and review available margin, not only the instantaneous value.

□ Review recent changes: maintenance, filters, setpoints, controls, doors, seals, equipment, schedules or room modifications.

□ Observe door openings, recovery and adjacent-space behavior under a comparable disturbance.

□ Evaluate whether the envelope or airflow-transfer paths have changed and whether new leakage paths or restrictions exist.

□ Review trends, alarms, control sequence, actuator saturation and possible sensor or signal problems.

□ Define what evidence will be required to consider the acceptable condition restored and who has authority to make that determination.

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

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

RELATED BIOLAB RESOURCES

GO DEEPER INTO THE SYSTEM

NT-010
Directional airflow as control logic

NT-011
Pressure cascades as state conditions

NT-012
Air changes per hour as a derived variable

NT-013
Failure modes in pressure-control systems

NT-014
HVAC as a risk-control mechanism

NT-015
Exhaust authority relative to supply

NT-016
Functional versus nominal HVAC redundancy

NT-017
HVAC control hierarchies and authority logic

NT-021–024
Envelope continuity, hermeticity and verification

NT-033
Functional testing versus compliance testing

NT-035
Documentation as containment control

NT-037 / NT-039
Maintenance risk and lifecycle drift

BIOLAB DIAGNOSTIC GUIDES

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

Series concept: symptom → system → evidence → restoration.

CLOSING DIAGNOSTIC PRINCIPLE

RESTORE THE RELATIONSHIP, NOT JUST THE READING.

Pressure instability is useful because it can reveal changes elsewhere in the containment system.

A pressure alarm may originate in instrumentation, controls, exhaust capacity, supply behavior, filter resistance, envelope leakage, door operation, adjacent rooms, maintenance or operational change.

Treating every alarm as an isolated HVAC problem encourages local corrections. Treating it as evidence of a changed system condition allows the technical team to identify the dependency that has actually moved.

The objective is not simply to recover a number on a display. It is to restore the relationship between boundary, airflow, control and operation that makes that number meaningful.

BIOLAB SOLUTIONS

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

Final production can add QR links to the relevant Technical Notes, service pages and downloadable checklist.

SYMPTOM → SYSTEM → EVIDENCE → RESTORATION