IS OUR CONTAINMENT BOUNDARY REALLY CONTINUOUS?

Diagnostic Guide
GD-008

A technical diagnostic guide to penetrations, doors, ceilings, service interfaces, and leak tightness

A practical guide to locating the containment boundary, identifying discontinuities, and determining where leakage, access, and interface conditions may compromise containment performance.

DIAGNOSTIC GUIDE

HOW TO USE THIS GUIDE

THE BOUNDARY IS NOT THE WALL. IT IS THE COMPLETE LINE THAT MUST REMAIN CONTROLLED.

This guide was created for facilities that have rooms, walls, and doors clearly represented on drawings but still have difficulty identifying where containment begins, ends, and becomes vulnerable.

Why we developed it

Containment boundaries are often treated as architectural surfaces. In practice, every service, door, ceiling interface, pass-through, autoclave, duct, cable tray, drain, and utility connection creates a point where the boundary must continue through a different detail.

Continuity problems can occur not because the primary wall construction is inadequate, but because interfaces were not coordinated, sealed, verified, or maintained as part of a continuous system.

The purpose of this guide is to help technical teams trace that system and identify where apparently minor discontinuities can change pressure behavior, decontamination capability, and lifecycle performance.

Who can use it

The guide is intended for architects, engineers, commissioning teams, facility managers, biosafety personnel, maintenance personnel, and project teams responsible for the design, construction, or operation of high-containment laboratories.

It may be used during design review, construction inspection, commissioning, diagnosis, periodic verification, or after modifications that alter the envelope.

HOW TO USE IT IN PRACTICE

First draw or identify the containment boundary. Then trace it physically and on the drawings, catalogue every interface that crosses it, determine how each one is sealed or controlled, and compare the installed condition with verification criteria appropriate to the facility.

The objective is not to make every room perfectly airtight. It is to ensure that leakage paths and interfaces are known, intentional where required, and consistent with the containment strategy.

01 LOCATE

02 TRACE

03 VERIFY

04 MAINTAIN

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 constitute a specific leak-tightness criterion, construction detail, specification, test protocol, certification, compliance determination, authorization to operate, or site-specific recommendation.

Technical and operational decisions

No decision regarding boundary acceptance, seal repair, modification of penetrations, continued operation, test criteria, or return to service should be based solely on this guide.

Applicable technical basis

The content should be interpreted together with the risk assessment, Basis of Design, approved construction details, commissioning and leak-tightness criteria, decontamination requirements, regulatory requirements, manufacturer instructions, and other site-specific documentation.

Competent personnel

Repairs, modifications, and verification of containment-critical interfaces should be designed, performed, or reviewed by appropriately qualified personnel using test methods suitable for the function of the boundary.

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.

First published: October 2026
Current version: October 2026 | v1.0

COPYRIGHT AND PERMITTED USE

© 2026 Biological Laboratory Solutions S.A.S. de C.V. All rights reserved.

This publication may be downloaded, retained, and used internally for educational, technical, and reference purposes.

It may not be reproduced, redistributed, modified, sold, or incorporated, in whole or in part, into commercial materials, courses, procedures, specifications, reports, or third-party publications without prior written authorization from BioLab Solutions.

Brief excerpts may be quoted with full attribution to BioLab Solutions and reference to the corresponding Diagnostic Guide.

01 Locate the boundary before evaluating it

A boundary cannot be verified if the project cannot identify where it is.

The containment boundary should be represented as a continuous line through plans, sections, and interfaces.

Trace it through

- walls;
- floors;
- ceilings or roof plane;
- doors;
- windows;
- pass-throughs;
- autoclaves;
- duct penetrations;
- service penetrations;
- drains and utility points.

Boundary location is a design decision

For each interface, the project should be able to answer:

- which side is contained;
- where sealing occurs;
- which component carries the boundary through the opening;
- how that condition will later be inspected or tested.

IF THE BOUNDARY CANNOT BE DRAWN CONTINUOUSLY, IT WILL BE DIFFICULT TO BUILD OR VERIFY IT CONTINUOUSLY.

02 Catalogue every penetration and interface

Containment becomes more vulnerable where another system must cross the envelope.

Interface	What requires review
Electrical	Conduit, cable trays, boxes, grouped penetrations, future spare openings, and seal compatibility.
Plumbing	Piping, sleeves, movement, insulation, drains, valves, and accessible sealing detail.
HVAC	Duct penetrations, housings, dampers, flexible connections, supports, and test access.
Doors	Frame-to-wall joint, leaf seals, thresholds, hardware penetrations, door closers, and interlocks.
Pass-throughs	Perimeter seal, door logic, service connections, maintainability, and decontamination interface.
Autoclaves / equipment	Wall opening, structural support, service penetrations, thermal movement, and maintenance access.
Ceiling / roof	Head-of-wall joints, supports, suspended services, access panels, and transitions to adjacent construction.

> **Coordination problem:** each discipline may correctly detail its own penetration while the combined opening still lacks a coordinated containment solution.

03 Distinguish visible finish from functional continuity

A clean, orderly surface does not necessarily establish a containment seal.

Sealants, coatings, and panels must function as part of an assembled boundary rather than simply provide a clean appearance.

Substrate

Is the material being sealed stable, compatible, and suitable for the expected movement and cleaning regime?

Joint geometry

Does the joint allow the sealant or elastomeric gasket to function as intended rather than simply fill a visible gap?

Movement

Can thermal, structural, or equipment movement break the seal over time?

Chemical compatibility

Will cleaning or gaseous decontamination degrade sealants, gaskets, coatings, or adhesives?

Access

Can the joint be inspected, repaired, or replaced without creating new uncontrolled openings?

Lifecycle condition

Has the interface been altered by maintenance, added cables, equipment changes, or repeated door adjustments?

LEAK TIGHTNESS IS A PROPERTY OF THE ASSEMBLY. IT DOES NOT COME FROM A FINISH MATERIAL ALONE.

04 Review doors as dynamic elements of the boundary

Doors are not static penetrations. They open, close, move, and wear repeatedly.

Inspect

- frame-to-wall perimeter;
- door-leaf seals;
- threshold or drop seal;
- hinges and alignment;
- door-closer performance;
- latching;
- hardware penetrations;
- interlock components.

Operational effect

A door can create two different boundary problems:

Closed condition: excessive leakage or poor sealing.

Transition condition: major pressure disturbance, poor recovery, or airflow reversal during operation.

Both belong in the containment review.

A DOOR IS PART OF THE BOUNDARY WHEN CLOSED AND PART OF THE AIRFLOW EVENT WHEN OPEN.

05 Pay particular attention to ceilings and areas behind equipment

Hidden interfaces are often the least coordinated and the most difficult to inspect later.

Head of wall

Where walls meet slabs, roofs, or plenum construction, confirm actual closure and service coordination.

Above-ceiling penetrations

Grouped cables, pipes, and supports can accumulate after construction and create uncontrolled leakage paths.

Behind equipment

Autoclaves, pass-throughs, and fixed casework can conceal perimeter joints that later become inaccessible.

Access panels

An access opening in the boundary should have a defined sealing and closure strategy.

Future services

Spare sleeves or abandoned penetrations should not remain as future unsealed paths.

Maintenance routes

Repeated access to filters, valves, sensors, or controls can damage seals that were never designed for frequent intervention.

> Concealed construction should be inspected before it becomes inaccessible when the interface is critical to containment.

06 Understand what leakage does to the mechanical system

Envelope performance and HVAC performance are coupled.

A ventilation system may maintain a room at negative pressure by compensating for greater leakage with more exhaust. This can preserve the displayed pressure differential while the condition of the system changes.

Excessive leakage may increase

- required exhaust airflow;
- fan speed;
- heating and cooling load;
- filter loading;
- demand on the control system;
- control sensitivity.

It may reduce

- available fan margin;
- pressure stability;
- resilience during door opening;
- future expansion capacity;
- confidence in decontamination performance.

NEGATIVE PRESSURE CAN MASK A LEAKY BOUNDARY BY FORCING THE FAN TO COMPENSATE FOR IT.

VERIFICATION

WHAT SHOULD A LEAK-TIGHTNESS TEST ACTUALLY TELL US?

A leakage test is useful only when the tested boundary, method, pressure condition, and acceptance criterion correspond to the containment function being evaluated.

Define the test boundary

Which surfaces, openings, and interfaces are intentionally included or excluded?

Define the method

Pressure decay, constant flow, or another accepted approach should be appropriate to the installation and the project criterion.

Define the acceptance basis

The criterion should be established before testing and linked to the required function.

Locate defects

An overall pass/fail result may require follow-up inspection or local leak detection to identify repair locations.

Retest after repair

Repairs should be followed by appropriate verification of the condition of the affected boundary.

Retain the result

Document the tested configuration, temporary closures, test pressure, result, repairs, and final accepted condition.

> Leak-tightness testing demonstrates performance under the defined test condition. It should not be interpreted as proof of every other containment function.

COMMON BOUNDARY FAILURES

WHAT OFTEN GOES WRONG

“The wall is sealed.”

The wall may be continuous while penetrations, frames, ceiling joints, or equipment interfaces are not.

“The room is negative, so the leaks are controlled.”

Negative pressure can coexist with excessive or poorly located leakage.

“The contractor used sealant everywhere.”

Sealant application alone does not establish appropriate joint design, substrate adhesion, or lifecycle durability.

“We can fix the penetrations later.”

Once services become dense and access is restricted, a correct repair may become much more difficult.

“The ceiling is not part of containment.”

That may or may not be correct. The project must define where the actual upper boundary is located.

“Nobody has touched it.”

Door wear, vibration, aging, cleaning chemistry, and maintenance can alter seals without a formal modification.

BOUNDARY FAILURE IS OFTEN INTERFACE FAILURE.

07 Review compatibility with decontamination

A boundary used for gaseous or vapor decontamination has an additional performance requirement.

Review

- room leakage under treatment conditions;
- seal and gasket compatibility;
- temporary openings;
- duct/isolation interfaces;
- drain and utility paths;
- penetration closures;
- monitoring points.

Do not assume

A room that maintains operational negative pressure is not automatically suitable for gaseous decontamination.

Leakage and material-compatibility requirements for a decontamination cycle may differ from those required for normal pressure control.

DIAGNOSTIC SEQUENCE

IS THE CONTAINMENT BOUNDARY REALLY CONTINUOUS?

01

Can the boundary be clearly located on drawings and in the facility?

No → define the containment line before evaluating individual interfaces.
Yes → continue.

02

Have all boundary penetrations and interfaces been identified?

No → complete an interface inventory and physical walkthrough.
Yes → continue.

03

Does each interface have a defined sealing/control strategy?

No → unresolved discontinuities require technical correction.
Yes → continue.

04

Is the installed condition accessible and consistent with the intended detail?

No → inspect concealed or field-modified conditions.
Yes → continue.

05

Has the boundary been verified using criteria appropriate to its function?

No → define and perform appropriate verification.
Yes → continue.

06

Are subsequent repairs, maintenance, and modifications controlled?

No → lifecycle drift may reopen the boundary.
Yes → the boundary has support as a maintained containment control.

WHAT SHOULD BE AVAILABLE?

Design

- boundary drawings;
- sections;
- penetration details;
- door details;
- equipment interfaces;
- acceptance criteria.

Construction

- submittals;
- mockups;
- concealed-work inspections;
- field changes;
- photographs;
- as-built records.

Verification

- leak-test results;
- local defect records;
- repairs;
- retesting;
- pressure/airflow data;
- accepted condition.

Lifecycle

- maintenance interventions;
- new penetrations;
- door repairs;
- sealant replacement;
- equipment changes;
- periodic inspections.

Review objective: maintain a traceable record of where the boundary is, how it is assembled, how it was verified, and what has changed since acceptance.

WHAT IF THE LABORATORY IS ALREADY OPERATING?

An operating facility can still reconstruct and evaluate its containment boundary even when original design documentation is incomplete.

Begin with a boundary walkthrough

- mark the intended containment line;
- photograph interfaces;
- catalogue penetrations;
- identify inaccessible areas;
- record field modifications;
- compare with current airflow behavior.

Prioritize by consequence

Not all defects require the same response.

Prioritize conditions affecting pressure stability, decontamination, direct leakage to uncontrolled areas, HEPA/exhaust boundaries, or interfaces that are frequently disturbed.

Use targeted testing where the consequence or uncertainty justifies it.

THE PURPOSE OF RETROSPECTIVE REVIEW IS TO TURN AN ASSUMED BOUNDARY INTO A KNOWN TECHNICAL CONDITION.

08 Define the level of boundary performance the function actually requires

BSL-3 does not automatically mean that every room must satisfy one universal leak-tightness value.

Boundary performance should be derived from the containment function: directional airflow, controlled leakage, gaseous decontamination, protection of adjacent spaces, pressure stability, or another defined requirement.

Function	Implication for the boundary
Directional airflow	Leakage distribution and opening behavior should support inward airflow and stable pressure relationships.
Pressure control	Total leakage should remain within the controllable range of the mechanical system and the accepted operating margin.
Gaseous / vapor decontamination	Leakage, isolation points, and material compatibility should support the selected decontamination method and exposure-control strategy.
Direct separation from uncontrolled space	Interfaces require a level of integrity consistent with the consequence of uncontrolled transfer across that boundary.
Maintainability	Seals and interfaces should remain inspectable, repairable, and restorable after foreseeable interventions.

> A leak-tightness test has meaning only when the test pressure, method, and acceptance criterion correspond to a defined boundary function. A stricter number is not automatically a better containment strategy.

MAINTAIN A BOUNDARY REGISTER, NOT ONLY A DRAWING

The boundary is easier to preserve when its interfaces are recorded as maintainable technical assets rather than rediscovered after every modification.

For critical interfaces, record

- location and unique reference;
- boundary function;
- component / penetration type;
- sealing or closure method;
- side accessible for inspection;
- applicable test or inspection method;
- date of last intervention;
- date/result of restoration verification.

Use it during change control

Maintenance, cabling, new services, equipment replacement, and room modifications should be reviewed against the register before work begins.

If an intervention crosses or opens the boundary, the work package should define temporary containment and the evidence required to restore the interface before return to service.

> **A BOUNDARY THAT CANNOT BE TRACED THROUGH CHANGE WILL GRADUALLY BECOME A DIFFERENT BOUNDARY.**

CAN WE TRACE THE BOUNDARY CONTINUOUSLY AND EXPLAIN EVERY INTERFACE?

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

□ Locate the intended containment boundary on current drawings and confirm that the as-built condition corresponds.

□ Trace walls, floor, ceiling / soffit, and all construction transitions that form part of the boundary.

□ Identify doors, frames, glazing, pass-throughs, autoclaves, and other intentional openings that cross the boundary.

□ Identify duct, cable, conduit, piping, drain, and service penetrations and confirm the sealing strategy at each interface.

□ Distinguish intentional air-transfer paths from uncontrolled leakage paths.

□ Review whether access panels, ceiling interfaces, and service zones create unreviewed communication with uncontrolled spaces.

□ Review areas repeatedly altered by maintenance, equipment replacement, or later penetrations for loss of continuity.

□ Confirm that the boundary remains compatible with required pressure-control, decontamination, and cleaning functions.

□ Use the verification method appropriate to the required function; do not infer leak tightness from room pressure alone.

□ Record critical interfaces, inspection/test method, intervention history, and unresolved defects in a boundary register or equivalent technical record.

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 BOUNDARIES, LEAK TIGHTNESS, AND SYSTEM INTERFACES IN GREATER DEPTH

NT-005–006
Containment closure, performance, and boundaries as design objects

NT-007–009
Penetrations, doors, airlocks, and pass-through interfaces

NT-018–020
HEPA filtration as a boundary system

NT-021–024
Leak tightness, envelope continuity, and verification

NT-025–028
Autoclaves, effluent systems, and terminal containment interfaces

NT-033
Functional testing versus compliance testing

NT-037
Maintenance as a containment-risk domain

NT-039
Lifecycle drift in containment systems

BIOLAB DIAGNOSTIC GUIDES

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

Series concept: symptom → system → evidence → restoration.

CLOSING DIAGNOSTIC PRINCIPLE

THE BOUNDARY IS ONLY AS CONTINUOUS AS ITS WEAKEST INTERFACE.

Containment boundaries are assembled from architecture, services, equipment, and operational interfaces.

The technical challenge is not simply to build sealed walls. It is to preserve continuity where the boundary changes material, crosses another system, opens for access, or is repeatedly altered during maintenance.

A reliable boundary can be located, inspected, tested, and maintained. Its leakage behavior is known, its interfaces are deliberate, and later modifications do not silently create new uncontrolled paths.

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.

BOUNDARY → INTERFACES → LEAKAGE → VERIFICATION