III-V SOLUTIONS
APPLICATION NOTE
AN-001

Leak Checking MOCVD Reactors

Rev-1.0

Best Practices for Establishing Vacuum Integrity

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Executive Summary

This application note captures practical field experience accumulated over decades of maintaining and commissioning MOCVD reactors. It is intended to supplement, not replace, equipment manufacturer documentation and site safety procedures. The emphasis is on engineering judgement, disciplined troubleshooting, and safe recommissioning after maintenance.

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1. Philosophy of Leak Checking

Unlike measuring voltage with a multimeter or checking continuity with an ohmmeter, leak checking is not a simple pass/fail measurement. There is no single numerical value that definitively declares an MOCVD reactor "leak free."

A helium leak detector provides valuable information, including leak rate and test port pressure, but it does not decide whether a reactor is ready for operation. That decision remains the responsibility of the engineer.

Leak checking should be viewed as an engineering judgment rather than a purely digital measurement. The leak detector provides data, but the engineer interprets that data in the context of the maintenance that was performed, the reactor design, the operating requirements, and the overall condition of the vacuum system.

A leak rate that may be perfectly acceptable on one reactor or process may not be acceptable on another. Likewise, excellent numerical readings do not automatically guarantee that a reactor is ready for hazardous process gases.

Ultimately, the decision to declare a reactor ready for service is based on both objective measurements and engineering experience.

One of the comments I often make while training engineers is that there is always one final leak check. If the reactor is not actually leak tight and hazardous gases are introduced, the building alarm system will quickly tell you that something is wrong.

Although I say this jokingly, the lesson is serious.

The building alarm system is **never** intended to be the leak detector.

The helium leak detector must identify every significant leak before combustible or toxic process gases are introduced into the reactor.

BULLOCK PRINCIPLE #1

A helium leak detector measures leaks. It does not determine whether a reactor is safe to operate. That decision belongs to the engineer.

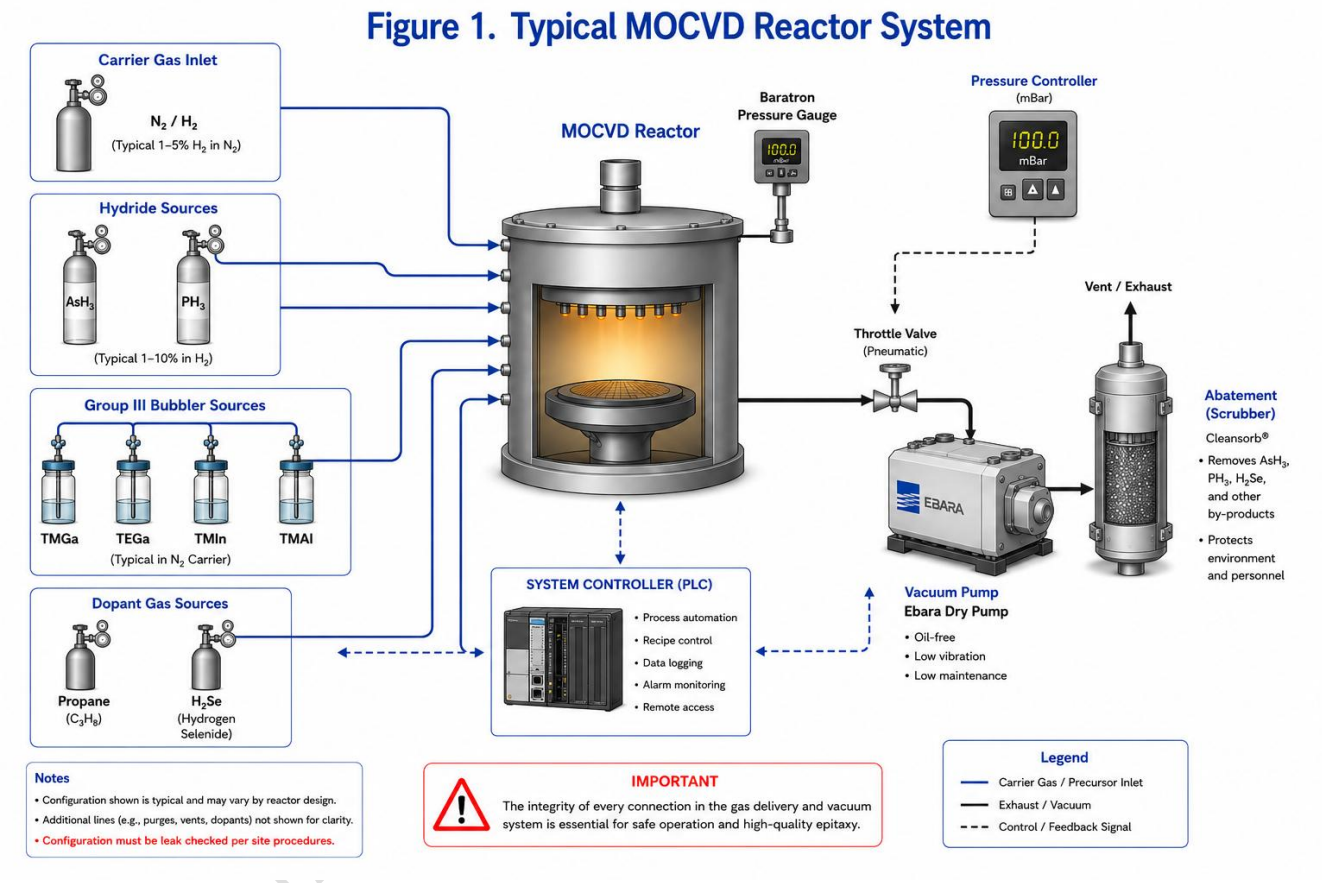


Figure 1. Typical MOCVD Reactor System

Figure 1 illustrates the major components of a typical horizontal MOCVD reactor system discussed throughout this application note.

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2. Inboard and Outboard Leak Checking

The engineer must first determine which leak-checking method is appropriate for the equipment being tested. There are two fundamental methods used throughout the semiconductor industry: **inboard leak checking** and **outboard leak checking**. The method selected depends entirely on the operating pressure of the system.

Understanding the difference between these two methods is essential because each one is designed for a different type of system. Choosing the wrong technique can lead to inaccurate results or unnecessary troubleshooting.

Inboard Leak Checking

An **inboard leak check** is used for systems that normally operate **below atmospheric pressure**. This is the method used for MOCVD reactors, load locks, transfer chambers, and other vacuum process equipment.

During an inboard leak check, the reactor is first evacuated to its normal operating vacuum. A helium mass spectrometer leak detector is connected to the vacuum system, and small amounts of helium are applied externally around potential leak locations.

If a leak exists, atmospheric pressure forces the helium through the leak path and into the evacuated reactor. The helium is then transported through the vacuum system to the helium leak detector where it is measured.

Because the helium is traveling **into** the vacuum system, this method is referred to as an **inboard** leak check.

Typical applications include:

- MOCVD reactors
- Vacuum chambers
- Load lock chambers
- Process transfer chambers
- High-vacuum semiconductor equipment
- Research vacuum systems

For virtually every maintenance activity involving an MOCVD reactor, the inboard leak check is the preferred and expected method.

Outboard Leak Checking

An **outboard leak check** is used for systems operating **above atmospheric pressure**.

Rather than evacuating the system, the piping or vessel is pressurized with an inert tracer gas mixture. A common mixture consists of approximately **90% nitrogen and 10% helium**.

The helium leak detector is operated in **sniffer mode**, and the probe is passed around fittings, valves, welds, threaded connections, VCR fittings, regulators, and other potential leak locations.

If helium escapes from the pressurized system, the sniffer detects the helium outside the piping.

Because the helium is traveling **out of** the system, this method is known as an **outboard** leak check.

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Typical applications include:

- Gas cabinets
- Gas panels
- Cylinder connections
- Process gas distribution piping
- High-pressure manifolds
- Pressurized gas delivery systems

Outboard leak checking should always be performed using an **inert tracer gas**. Toxic or combustible process gases should **never** be used for leak testing.

Selecting the Correct Method

The decision is actually very straightforward.

If the equipment normally operates at Low Pressure, perform an **inboard leak check**.

If the equipment normally operates under **positive pressure**, perform an **outboard leak check**.

This simple rule eliminates much of the confusion experienced by engineers who are new to semiconductor vacuum systems.

BULLOCK PRINCIPLE #2

Choose the leak-check method based on the operating pressure of the system—not on convenience.

Low Pressure systems are checked from the outside in.

Pressurized systems are checked from the inside out.

Engineering Note

Although this Application Note focuses primarily on **inboard leak checking of MOCVD reactors**, every MOCVD facility also contains numerous gas delivery components that require **outboard leak checking** during maintenance activities. Understanding both techniques allows the engineer to verify the integrity of the complete gas delivery system, from the gas cabinet to the reactor.

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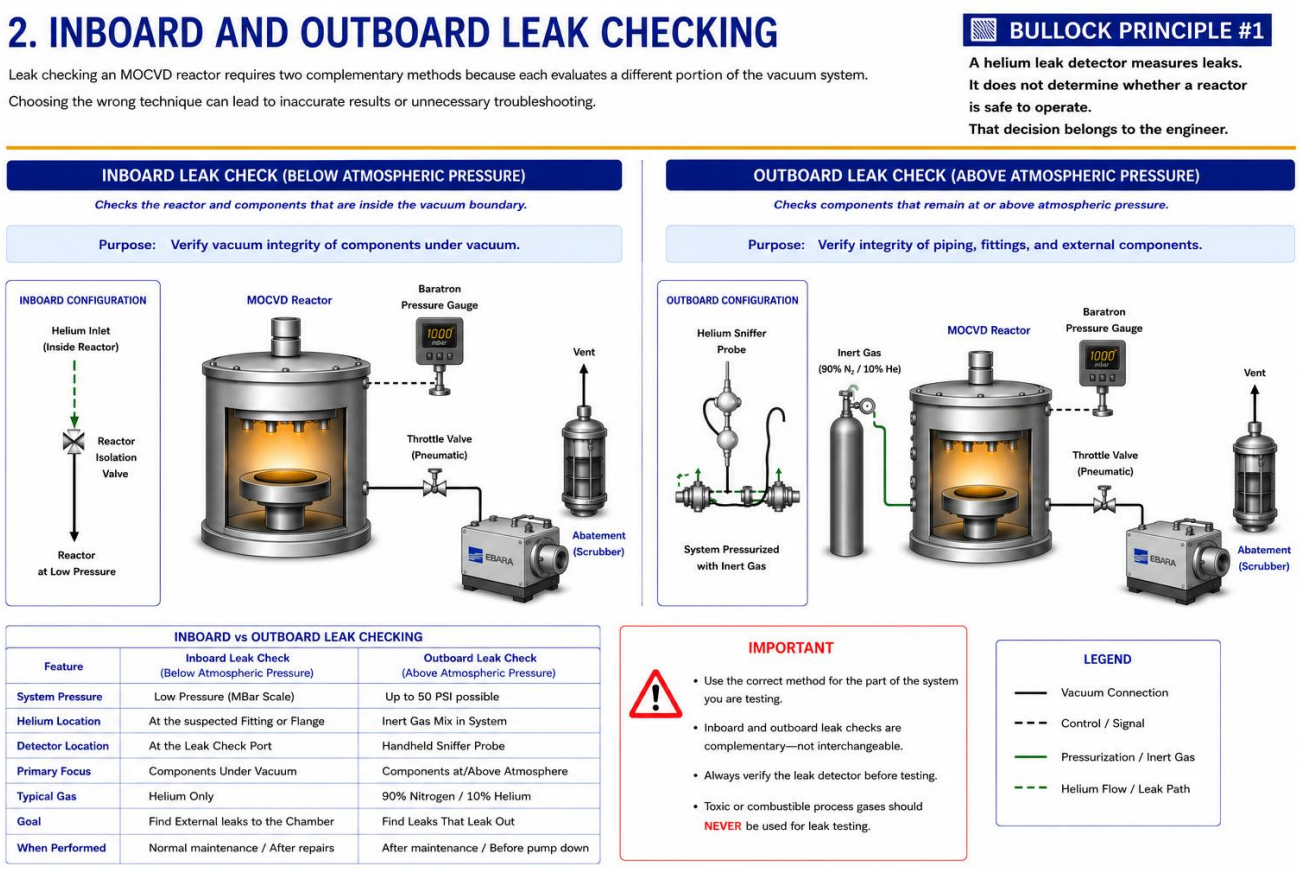


Figure 2. Inboard and Outboard Leak Checking Methods

Figure 2 compares the two primary helium leak-checking techniques used throughout the semiconductor industry. **Inboard leak checking** is performed on systems operating **below atmospheric pressure**, where helium is introduced externally and detected as it enters the evacuated vacuum system. **Outboard leak checking** is performed on systems operating **at or above atmospheric pressure**, where an inert nitrogen/helium mixture pressurizes the system and escaping helium is detected using a sniffer probe. Selecting the appropriate method depends entirely on the normal operating pressure of the component being evaluated.

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3. Preparing the Reactor for Leak Checking

Once the maintenance activity has been completed, the next step is preparing the reactor for leak checking. Proper preparation is just as important as the leak check itself. An improperly prepared reactor can produce misleading results, increase troubleshooting time, and in some cases create unnecessary mechanical stress on the equipment.

The objective during this phase is to establish a stable vacuum environment so that the helium leak detector can accurately evaluate the integrity of the reactor.

Controlled Pump Down

Rather than immediately evacuating the reactor to full vacuum, I prefer to bring the reactor down gradually.

My normal practice is to reduce the chamber pressure in approximately **100 mbar increments**. Although different facilities may use different procedures, this gradual pump-down minimizes unnecessary stress on reactor components, including quartz parts, seals, vacuum valves, and pressure control hardware.

As the chamber pressure decreases, continue monitoring the reactor until the chamber reaches approximately **100 mbar**.

At this point, I normally open the reactor throttle valve to **100 percent** and allow the vacuum system to evacuate the chamber to its normal base pressure.

The goal is to reach base pressure in a controlled and repeatable manner rather than simply pumping the reactor down as quickly as possible.

Reactor Configuration

During pump-down, the reactor should be configured so that only the systems required for evacuation remain active.

Typical configuration includes:

- Throttle valve fully open after approximately 100 mbar.
- Reactor evacuated using the normal vacuum pumping system.
- Nitrogen purge isolated as required.
- Hydrogen supply closed.
- All toxic process gases isolated.
- Metal-organic precursor lines isolated.
- Reactor allowed to stabilize at its normal base pressure.

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Under no circumstances should combustible or toxic process gases be introduced until vacuum integrity has been confirmed.

Two Independent Vacuum Systems

One concept I emphasize during training is that, before they are connected together, **the reactor and the helium leak detector are two completely independent vacuum systems.**

The reactor is being pumped down by its own vacuum pumps.

The helium leak detector is simultaneously pumping itself down using its own internal vacuum system.

Although they will eventually become one common vacuum system, at this stage they should be considered completely separate.

Each system must first demonstrate that it is capable of reaching an acceptable base pressure on its own.

Only after both systems have stabilized should they be connected together.

Thinking about the equipment this way helps prevent one of the most common mistakes made by inexperienced engineers—assuming the leak detector can somehow compensate for a reactor that has not been properly evacuated.

It cannot.

Both systems must independently demonstrate acceptable vacuum performance before the leak-checking process begins.

Verify the Leak Detector First

Before connecting the helium leak detector to the reactor, verify that the leak detector itself is operating properly.

The leak detector is not simply an instrument—it is a vacuum system containing pumps, valves, seals, flanges, and vacuum plumbing.

Like any other vacuum system, it can develop leaks.

For this reason, the leak detector should first be allowed to reach its own normal operating conditions.

Confirm that both:

- Leak Rate
- Test Port Pressure

are within acceptable limits before connecting it to the reactor.

If the leak detector itself is not operating correctly, confidence in every measurement that follows is reduced.

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"Measure the Yardstick"

When training technicians and engineers, I often use a simple expression:

Always measure the yardstick before you use it to measure something else.

The helium leak detector is the measuring instrument.

Before using it to evaluate the reactor, first prove that the instrument itself is functioning correctly.

If the measuring instrument has a problem, the measurements it produces cannot be trusted.

This simple concept eliminates a tremendous amount of unnecessary troubleshooting.

Connecting the Leak Detector

Once both the reactor and the helium leak detector have independently reached acceptable base pressure, the two systems can be connected.

A typical sequence is:

1. Place the helium leak detector in **Standby**.
2. Open the isolation valve between the reactor and the leak detector.
3. Press the **Evacuate** function on the helium leak detector.
4. Allow the leak detector to evacuate the connecting volume.
5. Wait for both the **Leak Rate** and **Test Port Pressure** to stabilize.

At this point, the reactor and the helium leak detector are no longer independent systems.

They have become **one common vacuum system**, and the leak detector is now monitoring the entire reactor volume.

Only after the combined system has stabilized should helium be introduced for leak checking.

BULLOCK PRINCIPLE #3

Before leak checking the reactor, first prove that the leak checker is operating correctly.

Never measure an inch using a yardstick.

Before evaluating the reactor, first prove that the helium leak detector is operating correctly. If the measuring instrument cannot be trusted, neither can the measurements it produces.

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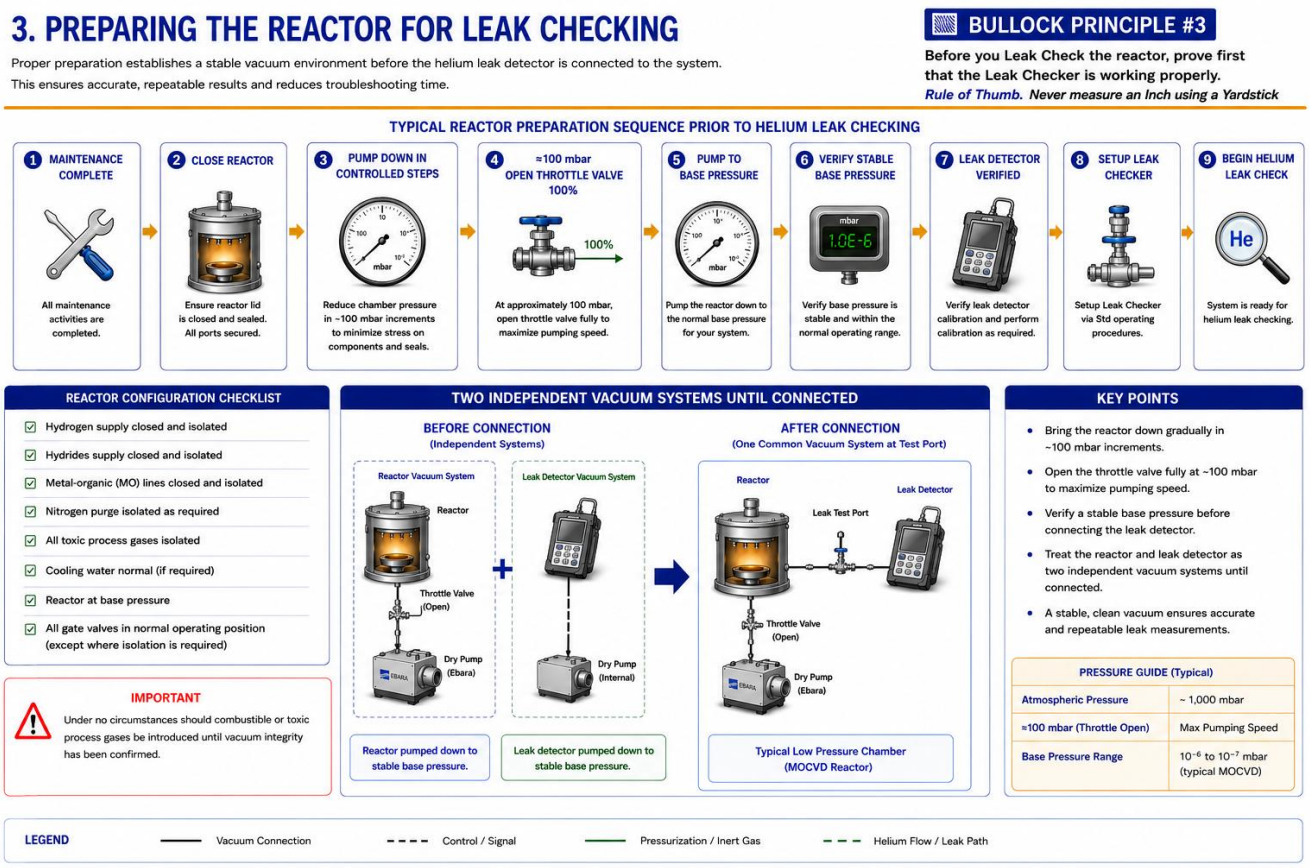


Figure 3. Preparing for Leak Checking

Proper leak checking begins long before the detector is turned on. This figure outlines the essential preparation steps, including selecting the correct tracer gas, verifying instrument readiness, ensuring system stability, and reviewing safety requirements. Careful preparation improves leak detection accuracy, reduces false indications, and establishes a safe foundation for effective troubleshooting.

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4. Performing the Leak Check

Once the reactor and helium leak detector have stabilized as a single vacuum system, the actual leak check can begin.

This is the point where patience and discipline become just as important as the equipment itself. Many leak-checking problems are not caused by defective instruments but by rushing the process or using poor technique.

The objective is simple: systematically inspect every component that was disturbed during maintenance while eliminating variables that can produce false indications.

Where Should You Leak Check?

One of the first questions new engineers ask is:

"Where do I start?"

The answer is equally simple.

Leak check every component that was disturbed during the maintenance activity.

If a flange was opened, it should be checked.

If an O-ring was replaced, it should be checked.

If a pressure controller was replaced, it should be checked.

If a valve was removed, it should be checked.

The leak detector is not intended to inspect the entire reactor after every maintenance activity. Instead, it is verifying the integrity of the components that were disturbed.

Typical locations include:

- VCR fittings
- CF flanges
- KF flanges
- Pressure controllers
- Pressure gauges
- Viewports
- Quartz chamber seals
- Turbo pump connections
- Gate valves
- Vacuum valves

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- Gas panel fittings
- Mass flow controller connections
- Filter housings

These are the highest probability locations for maintenance-induced leaks.

BULLOCK PRINCIPLE #4

If you touched it, leak check it.

Every flange that was opened...
Every fitting that was loosened...
Every seal that was replaced...

Those are the first places that deserve your attention.

Start at the Top

One practice that has served me well throughout my career is always beginning the leak check at the **highest point of the reactor**.

From there, work methodically downward.

This is not simply personal preference—it is based on physics.

Helium is lighter than air.

If helium is applied to a fitting near the bottom of the reactor, it naturally rises around the equipment.

As it rises, it can collect around higher fittings and flanges.

An engineer may then incorrectly believe an upper flange is leaking when, in reality, the helium originated from somewhere below.

Beginning at the top minimizes this possibility and makes locating the actual leak much easier.

Work slowly.

Move in one direction.

Never jump randomly around the reactor.

A systematic approach almost always identifies leaks more quickly than a random search.

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BULLOCK PRINCIPLE #5

Using the Correct Amount of Helium

One of the most common mistakes I see is using far too much helium.

Many engineers assume that more helium will make leaks easier to find.

In reality, the opposite is usually true.

Flooding the reactor with helium raises the background helium concentration around the equipment and can make it extremely difficult to determine where the leak actually exists.

A successful leak check requires only a **very small amount of helium**.

The goal is to expose one fitting or flange at a time—not the entire reactor.

Learning How Little Helium Is Required

One of the senior technicians who trained me demonstrated this lesson in a way I have never forgotten.

He placed the helium probe into a glass of water and slowly adjusted the flow until only a very slow stream of bubbles was produced.

The purpose wasn't to measure a precise flow rate.

The lesson was simply to demonstrate how surprisingly little helium is actually required to perform an effective leak check.

That lesson has stayed with me throughout my career.

Another practical shop technique involved moistening the lower lip and briefly directing a tiny puff of helium toward it.

If only the slightest sensation of helium could be felt, the flow was generally appropriate.

Again, this was never intended as a calibration method.

It was simply a practical reminder that **less is usually better**.

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BULLOCK PRINCIPLE #6

More helium does not produce a better leak check.

Small, controlled applications almost always produce better results than flooding the reactor with helium.

Allow the Leak Detector to Respond

Perhaps the biggest mistake made by inexperienced engineers is moving too quickly.

After applying helium to a flange or fitting...

Wait.

Give the helium time to travel through the leak path.

Give the vacuum system time to transport the helium.

Give the helium leak detector time to respond.

Depending on reactor volume and vacuum conductance, the response may take **20 to 30 seconds**.

Moving to the next flange too soon often creates confusion because the detector response may actually correspond to the previous location.

Patience is one of the most valuable leak-checking skills an engineer can develop.

Reading the Response

Not every change in the leak detector indicates a significant leak.

Occasionally, the leak rate may increase slightly before quickly returning to its baseline value.

Minor transient responses like this are often insignificant.

What deserves attention is a **repeatable** response.

If the leak rate increases from approximately $\mathbf{1.0 \times 10^{-9}}$ to $\mathbf{1.0 \times 10^{-8}}$ or even $\mathbf{1.0 \times 10^{-7}}$, and the response can be repeated by applying helium to the same location, the engineer should consider that fitting or flange suspect.

Repeatability is one of the strongest indicators that a genuine leak has been identified.

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BULLOCK PRINCIPLE #7

Don't chase every needle movement.

Look for a clear, repeatable response before declaring that a leak exists.

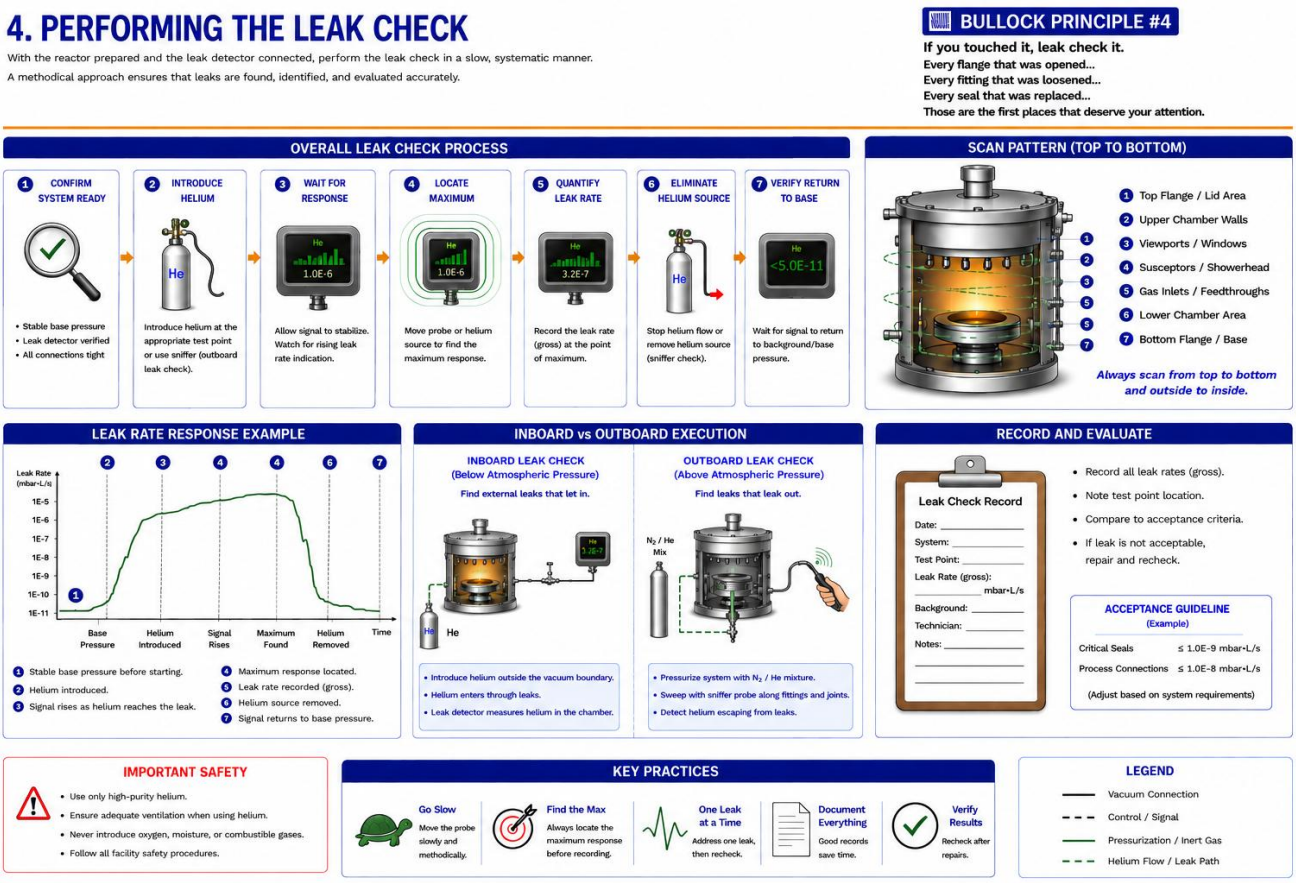


Figure 4. Performing the Leak Check

Performing an effective leak check requires a systematic and disciplined approach. This figure illustrates proper probe handling techniques, recommended scan patterns, detector response interpretation, and methods for isolating leak sources. Following these best practices improves leak detection accuracy, minimizes false readings, and ensures reliable verification of system integrity before returning equipment to service.

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5. Understanding Leak Detector Readings

The helium leak detector is an extremely sensitive instrument. However, like any precision measuring device, it is only as useful as the engineer interpreting its readings.

Throughout my career I have encouraged engineers to avoid focusing on a single number. The leak detector provides multiple pieces of information, and each one contributes to the overall assessment of the reactor's vacuum integrity.

The two values I pay the closest attention to are:

- **Leak Rate**
- **Test Port Pressure**

Both are important.

Both should be evaluated together.

Neither should be ignored.

Leak Rate

The leak rate is the primary indication of helium entering the vacuum system.

Every reactor manufacturer has its own acceptance criteria, and some applications require tighter limits than others. Nevertheless, over many years of working with MOCVD equipment, I have found that a leak rate of approximately:

1.0×10^{-9}

is generally a good target for a properly sealed reactor.

The exact number is less important than understanding what the detector is telling you.

The leak rate should remain stable while the reactor is being evaluated.

Unexpected changes deserve investigation.

Test Port Pressure

The second value I always monitor is the **Test Port Pressure**.

For most leak checks, I prefer to see a value near:

1.0×10^{-3} mbar

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This indicates that the helium leak detector is operating within its intended measurement range.

Even an excellent leak rate should be viewed with caution if the detector itself is not operating under proper vacuum conditions.

Always verify the detector is operating within its recommended test port pressure before beginning a detailed leak search.

Both Numbers Tell the Story

One mistake I occasionally observe is an engineer concentrating only on the leak rate.

The leak rate tells you what the detector is seeing.

The test port pressure tells you how well the detector itself is operating.

Looking at only one of these values is like driving a car while watching only the speedometer and ignoring the fuel gauge, oil pressure, and engine temperature.

Good engineering decisions require the complete picture.

Engineering Judgment

The leak detector cannot decide whether a reactor is acceptable.

It simply provides information.

The engineer must combine that information with:

- The maintenance that was performed.
- The location being tested.
- The magnitude of the response.
- Whether the response is repeatable.
- The operating requirements of the reactor.

Only then can the reactor be judged ready—or not ready—for operation.

This is why I say leak checking is fundamentally an engineering judgment rather than a simple numerical measurement.

Establishing a Baseline

Before introducing helium to the reactor, take a few moments to observe the leak detector.

Watch the readings.

Allow the instrument to stabilize.

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Become familiar with the normal background readings.

This establishes a baseline against which every subsequent response can be compared.

Without a stable baseline, interpreting small changes becomes much more difficult.

Avoid Chasing Noise

Every leak detector exhibits small fluctuations.

Tiny changes in the displayed leak rate are completely normal.

Do not assume every movement of the display represents a leak.

Instead, look for responses that are:

- Repeatable.
- Significant.
- Clearly associated with helium being applied to a specific fitting or flange.

A true leak tells a consistent story.

Random fluctuations do not.

BULLOCK PRINCIPLE #8

The leak detector gives you information—not answers.

Engineering judgment is what transforms measurements into decisions.

BULLOCK PRINCIPLE #9

Always establish a stable baseline before you begin leak checking.

If you don't know what "normal" looks like, you won't recognize a problem when you see it.

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Engineering Tip

One habit I've developed over the years is resisting the temptation to react immediately to every change on the display.

Instead, I ask three questions:

1. **Did I actually apply helium to this location?**
2. **Is the response repeatable?**
3. **Does the magnitude of the response make engineering sense?**

If the answer to all three questions is yes, then I have confidence that I've identified a genuine leak.

If not, I continue observing before making any decisions.

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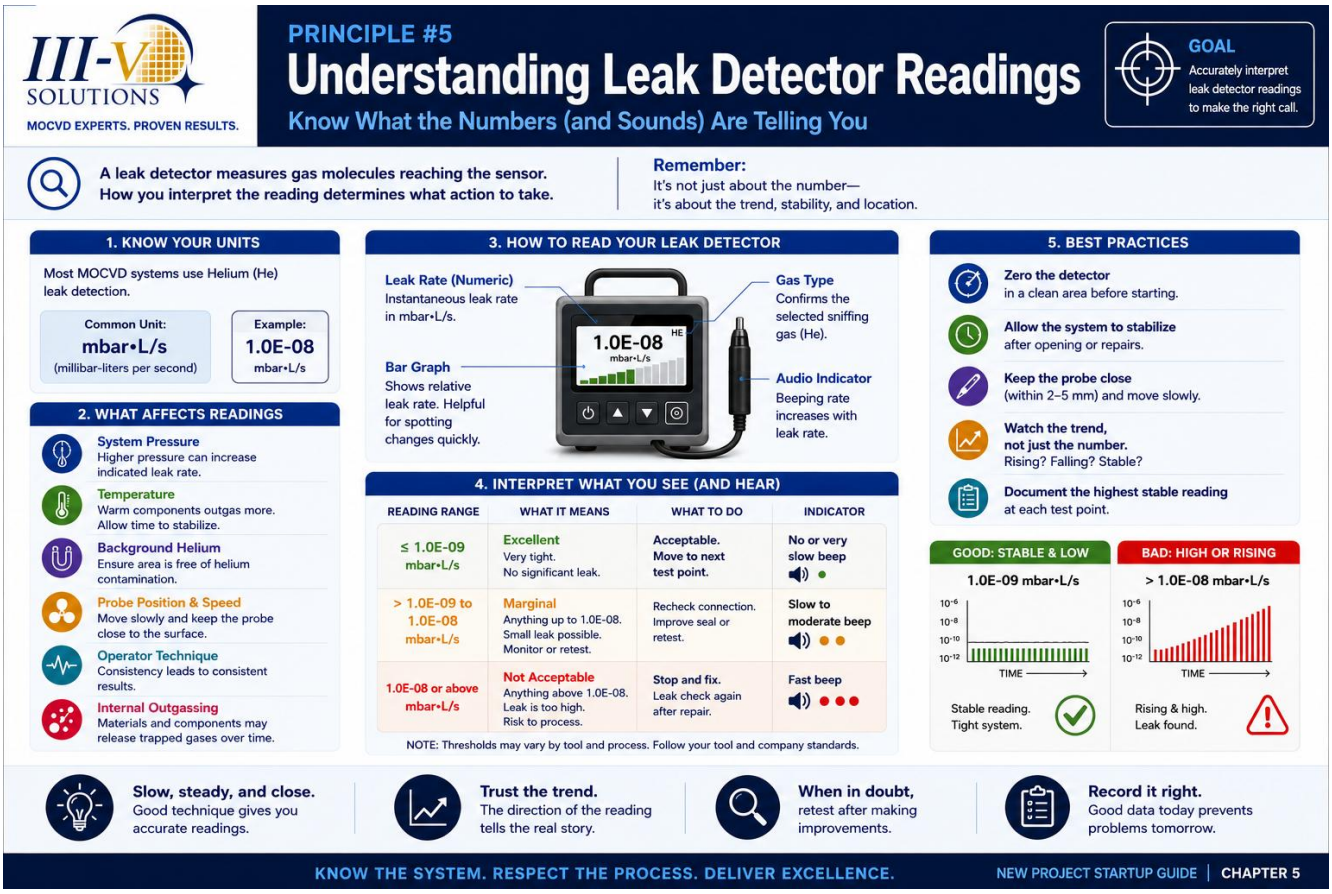


Figure 5. Understanding Leak Detector Readings

Accurate interpretation of leak detector readings is essential for distinguishing normal background conditions from true system leaks. This figure explains leak rate units, factors that influence detector response, acceptable leak thresholds, and how to recognize stable, marginal, and unacceptable readings. Understanding both the measured value and its trend enables technicians to make informed decisions, avoid unnecessary repairs, and maintain safe, high-quality MOCVD operations.

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6. Repairing and Verifying Leaks

Finding a leak is only half of the job.

The real objective is to restore the integrity of the reactor and prove that the repair was successful before returning the system to service.

One mistake I occasionally see is an engineer continuing to leak check additional areas after a significant leak has already been found.

I strongly discourage this practice.

Once a leak has been identified, stop the leak check.

Repair the leak.

Verify the repair.

Only then continue inspecting the remainder of the reactor.

This systematic approach removes uncertainty from the troubleshooting process and ensures that each repair is evaluated independently.

Stop and Repair

When the helium leak detector produces a significant, repeatable response indicating a leak, the first responsibility is to repair that leak.

Do not continue spraying helium on additional fittings.

Do not assume that all of the leaks can be found first and repaired later.

Doing so introduces unnecessary variables into the troubleshooting process.

Instead, focus on one problem at a time.

Record the location of the leak.

Determine the most likely cause.

Prepare the reactor for repair.

Only after the repair has been completed and verified should the engineer continue with the remainder of the leak check.

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Performing the Mechanical Repair

Once the leaking location has been identified, follow the facility's approved mechanical maintenance procedure.

Although procedures vary from facility to facility, the basic sequence is generally the same.

The reactor should be safely returned to atmospheric pressure using **dry nitrogen** in accordance with established operating procedures.

Once the reactor has been vented, disconnect the leaking flange or fitting.

Carefully inspect every sealing surface.

Do not assume that replacing a gasket alone will correct the problem.

Inspect for:

- Scratches
- Dents
- Contamination
- Damaged sealing surfaces
- Improper alignment
- Particles
- Damaged threads
- Improper gasket installation

Many persistent leaks are ultimately traced to damaged sealing surfaces rather than defective gaskets.

Replace Sealing Hardware

Whenever a metal seal has been disturbed, install a **new VCR gasket**.

Do not reuse previously compressed metal gaskets.

Likewise, elastomer seals should be carefully inspected and replaced whenever there is any doubt regarding their condition.

The cost of a new gasket is insignificant compared to the time required to repeatedly vent and pump down a reactor because an old seal was reused.

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BULLOCK PRINCIPLE #10

Every time a flange is opened, install new sealing hardware.

Never assume a used gasket will seal properly a second time.

Verify the Repair

Completing the mechanical repair does **not** complete the leak repair.

The repair must now be verified.

Pump the reactor back to its normal base pressure using the same controlled pump-down procedure used previously.

Reconnect the helium leak detector.

Allow both systems to stabilize.

Return to the exact location that was repaired.

Repeat the helium leak check.

If the detector no longer responds, the repair has been successfully completed.

Only then should leak checking continue elsewhere on the reactor.

If the Leak Remains

Occasionally, a leak will still be present after the first repair attempt.

If this occurs, resist the temptation to accept the result or move on to another area.

Instead:

- Vent the reactor again using dry nitrogen.
- Disassemble the connection.
- Reinspect every sealing surface.
- Verify component alignment.
- Install new sealing hardware if necessary.

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- Reassemble the connection.
- Pump the reactor back down.
- Repeat the helium leak check.

Continue this process until the repair has been positively verified.

Never assume the repair was successful simply because the reactor was reassembled.

Only the helium leak detector can confirm that the leak has actually been eliminated.

BULLOCK PRINCIPLE #11

Never assume a repair is successful.

***Prove it* !!!**

Every repair deserves another leak check.

Every repair must earn your confidence.

One Leak at a Time

Throughout my career, one practice has consistently reduced troubleshooting time.

Find one. Fix one. Verify one. Then move on.

By limiting the troubleshooting process to a single leak at a time, the engineer always knows the current condition of the reactor.

If multiple repairs are attempted simultaneously, it becomes much more difficult to determine which repair corrected the problem—or whether a new problem was introduced during maintenance.

Simple, disciplined troubleshooting almost always produces the fastest results.

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BULLOCK PRINCIPLE #12

Find one. Fix one. Verify one. Then move on.

This simple rule has saved countless hours of unnecessary troubleshooting throughout my career.

Workshop Tip

One of the habits I've developed over the years is treating every repair as though I'm going to inspect it again tomorrow.

That mindset encourages careful workmanship the first time, proper torque on every fitting, clean sealing surfaces, and a methodical verification of the completed repair.

In my experience, **careful workmanship is usually faster than rushed workmanship** because it avoids having to perform the same repair twice.

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Figure 6. Repairing and Verifying Leaks

Locating a leak is only the first step—effective repair and thorough verification are essential to restoring system integrity. This figure outlines common leak repair techniques, methods for confirming repair effectiveness, and the importance of documenting results before returning equipment to operation. A disciplined repair and verification process ensures safe operation, minimizes repeat maintenance, and maintains the reliability and performance expected in MOCVD manufacturing.

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7. Hydrogen Verification and Return to Service

The successful completion of a helium leak check does not automatically mean the reactor is ready for production.

The helium leak check verifies the integrity of the vacuum system. Before hazardous process gases are introduced, the gas delivery system should also be verified under operating conditions.

This is accomplished using hydrogen.

Hydrogen is typically the first process gas introduced following maintenance because it allows the engineer to verify the integrity of the gas delivery system before introducing highly toxic process gases such as arsine or phosphine.

For this reason, hydrogen verification should be considered the final engineering confirmation that the repaired reactor is ready to return to service.

Preparing for Hydrogen Verification

Once every repaired flange and fitting has successfully passed the helium leak check, isolate the helium leak detector from the reactor.

Close the isolation valve connecting the leak detector to the reactor.

The reactor can now be prepared for gas introduction using the facility's approved operating procedures.

At this point, the reactor has successfully demonstrated acceptable vacuum integrity and is ready for verification under actual process gas conditions.

Initial Hydrogen Introduction

The first introduction of hydrogen should always be performed cautiously.

Do not immediately introduce hydrogen at full process flow.

Instead, begin with a relatively low flow rate.

A typical starting point is approximately **50 sccm**, although this value may vary depending upon reactor design and facility operating procedures.

The objective is not process operation.

The objective is verifying that every component disturbed during maintenance remains leak tight under gas pressure.

Using a Combustible Gas Detector

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During hydrogen introduction, use a calibrated combustible gas detector to inspect every fitting, flange, valve, regulator, pressure controller, and connection that was disturbed during maintenance.

Move methodically around the reactor.

Inspect every repaired location.

Allow sufficient time for the combustible gas detector to respond before moving to the next fitting.

The same patience required during helium leak checking also applies during hydrogen verification.

Increase to Operating Conditions

If no combustible gas is detected during the initial low-flow verification, increase the hydrogen flow to the normal process operating conditions.

Repeat the inspection of every repaired fitting and flange.

Verify that no combustible gas is detected at either low flow or normal operating flow.

Successful verification at both operating conditions provides confidence that the repair has restored the integrity of the gas delivery system.

Never Begin with Toxic Process Gases

One principle has remained constant throughout my career.

Never use toxic process gases to determine whether a repair was successful.

The purpose of hydrogen verification is to establish confidence in the repaired system before introducing materials that present significantly greater hazards.

Only after hydrogen verification has been successfully completed should gases such as:

- Arsine (AsH_3)
- Phosphine (PH_3)
- Trimethylgallium (TMGa)
- Trimethylaluminum (TMAl)
- Other hazardous precursors

be introduced into the reactor.

The engineer should never allow the first indication of a poor repair to come from a toxic gas monitor or combustible gas alarm.

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BULLOCK PRINCIPLE #13

Verify with hydrogen before introducing toxic process gases.

Earn the right to use hazardous process gases.

First prove that the repaired system performs safely using hydrogen.

Only then proceed to normal reactor operation.

Final Acceptance

At the completion of hydrogen verification, the engineer should have confidence that:

- Every disturbed flange and fitting has been inspected.
- Every leak identified during helium leak checking has been repaired.
- Every repair has been verified.
- Acceptable leak rate and test port pressure have been demonstrated.
- Hydrogen verification has been successfully completed.
- No combustible gas leaks have been detected.

Only after these conditions have been satisfied should the reactor be returned to normal production service.

BULLOCK PRINCIPLE #14

A Reactor is not ready for production because the maintenance is complete.

It is ready because every repair has been verified.

Even very small leaks can allow atmospheric contamination...

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Even very small leaks can allow atmospheric contamination to enter the reactor.

Among atmospheric contaminants, **oxygen and moisture are particularly harmful** to many III-V epitaxial growth processes. Their presence can degrade crystal quality, alter material properties, reduce device performance, and lower manufacturing yield.

In my experience, **oxygen is a killer for laser diode structures**. Maintaining a leak-tight reactor is therefore essential not only for personnel safety, but also for producing high-quality epitaxial material. A properly leak-checked reactor provides the controlled environment required for consistent crystal growth and repeatable device performance.

A leak-free reactor is therefore not simply a safer reactor.

It is also a reactor capable of producing the highest quality epitaxial material.

Good leak checking protects people.

Good leak checking protects equipment.

Good leak checking protects the manufacturing process.

Good leak checking protects product quality.

Ultimately, good leak checking protects every wafer that leaves the reactor.

Throughout my career, I have found that successful leak checking has very little to do with luck. It is the result of careful preparation, patience, disciplined troubleshooting, and sound engineering judgment.

The helium leak detector provides the measurements.

The engineer provides the experience.

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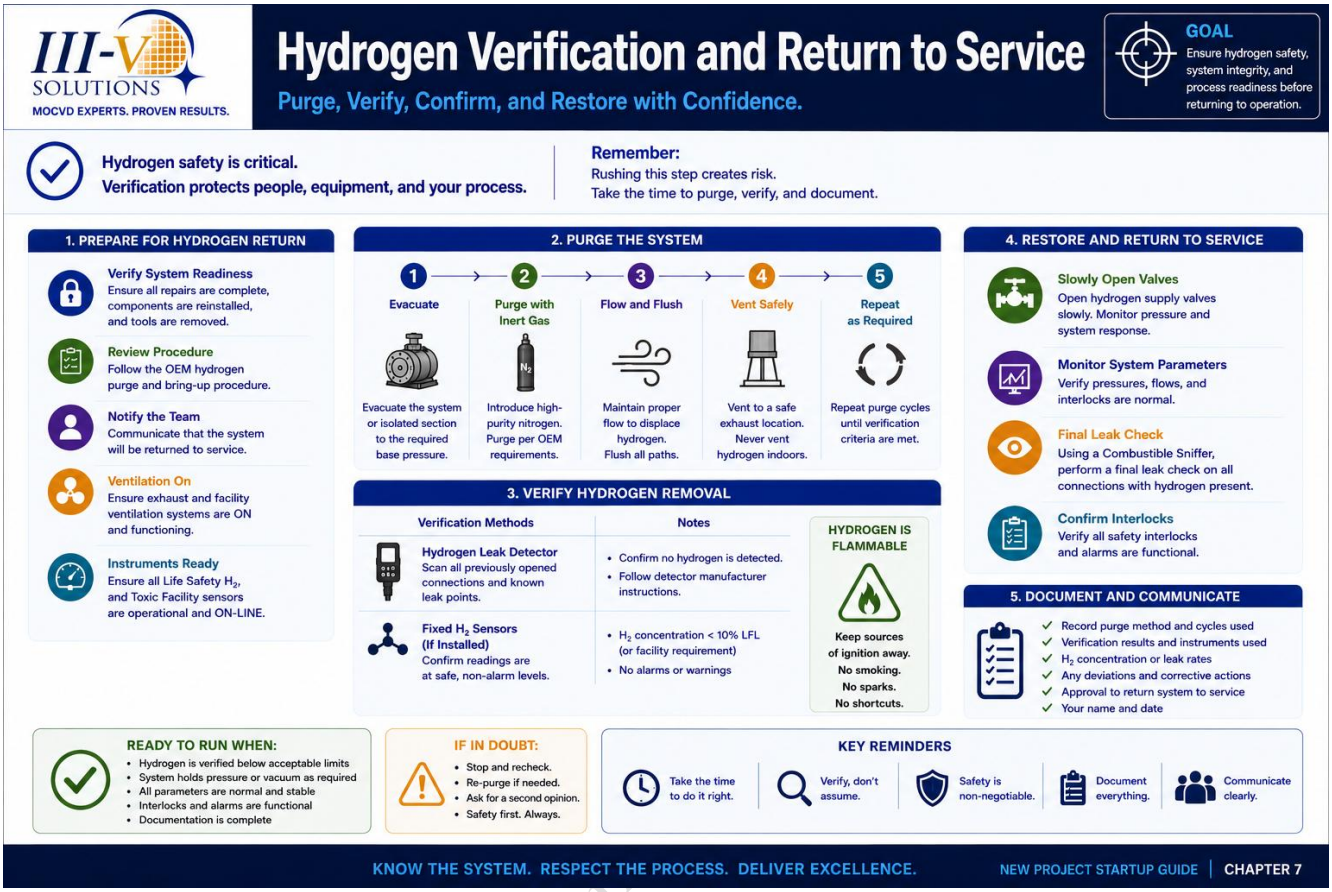


Figure 7. Hydrogen Verification and Return to Service

Before returning an MOCVD system to production, all hydrogen systems must be verified to ensure safe and reliable operation. This figure describes the final safety checks, confirmation that life safety hydrogen and toxic gas monitoring systems are operational, verification of gas system integrity, and completion of a final leak check using a combustible gas detector. Following these procedures minimizes personnel risk, protects valuable equipment, and ensures the reactor is ready for safe production.

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8. Why Leak Checking Matters

Throughout this application note, I have emphasized that leak checking is far more than a routine maintenance task. It is one of the most important engineering responsibilities performed on an MOCVD reactor because it directly affects **personnel safety**, **equipment reliability**, and **epitaxial material quality**.

A successful leak check provides confidence that the reactor and gas delivery system are ready for operation. More importantly, it confirms that the engineer has done everything possible to protect the people working around the equipment while preserving the integrity of the manufacturing process.

Personnel Safety

The first responsibility of every engineer is to ensure the safe operation of the equipment.

MOCVD systems routinely use gases that are combustible, pyrophoric, corrosive, and highly toxic. Hydrogen, arsine, phosphine, ammonia, and numerous metal-organic precursors present significant hazards if they are allowed to escape from the gas delivery system or reactor.

A properly executed leak check is one of the final opportunities to identify and correct leaks before these hazardous materials are introduced into the process.

No engineer should ever rely on combustible gas detectors or toxic gas monitors to discover a leak that should have been found during maintenance.

Those monitoring systems exist to protect personnel during an emergency—not to replace good engineering practice.

Every leak that is repaired before introducing process gases is one less opportunity for an accident to occur.

Equipment Reliability

Leak checking also contributes directly to the long-term reliability of the reactor.

Vacuum leaks often result in unstable pressure control, inconsistent gas flow, increased pump loading, contamination of vacuum components, and unnecessary downtime.

Even relatively small leaks can create intermittent process problems that require hours or even days of troubleshooting.

By verifying every repair before returning the reactor to production, the engineer greatly reduces the likelihood of unexpected failures during process operation.

A properly leak-checked reactor is simply a more reliable reactor.

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Product Quality

Leak checking is equally important to the quality of the epitaxial material being grown.

The objective of an MOCVD reactor is to produce highly controlled crystal growth in an extremely clean environment.

Even very small leaks can allow atmospheric contamination to enter the reactor.

Among atmospheric contaminants, **oxygen and moisture are particularly harmful** to many III-V epitaxial growth processes. Their presence can alter crystal growth, affect electrical properties, increase defect densities, reduce manufacturing yield, and degrade overall device performance.

In my experience, **oxygen is a killer for laser diode structures**.

Maintaining a leak-tight reactor is therefore essential not only for personnel safety, but also for producing high-quality epitaxial material. A properly leak-checked reactor provides the controlled environment necessary for repeatable crystal growth and consistent device performance.

A leak-free reactor is not simply a safer reactor.

It is also a reactor capable of producing the highest quality epitaxial material.

Engineering Responsibility

One lesson I have learned throughout my career is that successful leak checking has very little to do with luck.

It is the result of preparation.

It is the result of patience.

It is the result of disciplined troubleshooting.

Most importantly, it is the result of sound engineering judgment.

The helium leak detector provides valuable measurements.

The engineer interprets those measurements and decides whether the reactor is truly ready for operation.

Technology continues to improve, but no instrument can replace the experience, discipline, and responsibility of the engineer performing the work.

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Figure 8. Why Leak Checking Matters

Synopsis:
Leak checking is a critical practice that protects personnel, preserves equipment, and ensures the production of high-quality semiconductor devices. This figure highlights the importance of preventing hazardous gas releases, maintaining process integrity, reducing downtime, and safeguarding product yield through effective leak detection. Consistent leak checking reinforces a culture of safety, operational excellence, and continuous quality improvement throughout every stage of MOCVD manufacturing.

I think this is a fitting conclusion to the guide. It ties together the two overarching themes we've emphasized throughout the document: **Safety First** and **Device Quality Through Process Integrity**. It leaves the reader with a clear understanding of *why* every leak check matters, not just *how* to perform one.

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Final Thoughts

Good leak checking protects people.

Good leak checking protects equipment.

Good leak checking protects the manufacturing process.

Good leak checking protects product quality.

Ultimately, good leak checking protects every wafer that leaves the reactor.

If the principles presented in this application note help another engineer perform leak checking more safely, more consistently, and with greater confidence, then this document has achieved its purpose.

BULLOCK FINAL PRINCIPLE™

A leak-free reactor is more than a maintenance achievement.

It is the foundation of safe operation, reliable operation, and high-quality MOCVD epitaxy.

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From the Author

The techniques presented in this application note represent lessons learned over more than four decades of working with MOCVD equipment in research laboratories, pilot production facilities, and high-volume semiconductor manufacturing.

My hope is that the knowledge shared here helps the next generation of MOCVD engineers approach leak checking with greater confidence, sound engineering judgment, and an appreciation for the relationship between **safety, reliability, and epitaxial quality**.

If these pages help prevent a hazardous gas release, solve a difficult vacuum problem, improve reactor reliability, or contribute to better epitaxial material, then they have fulfilled their purpose.

Engineering knowledge becomes truly valuable only when it is shared.

Robert F. Bullock
Founder & Principal Consultant
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