PRODUCTION LEAK TESTING

Optimizing Helium Usage and Alternate Test Methods

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President, CEO

LACO TECHNOLOGIES

Overview

- Helium leak testing **applications** and **methods**
- Why we use **helium**
- Where helium **comes from** and where **it is used**
- Helium **supply issues** and **trends**
- Helium usage **strategies**
- Alternate **leak testing methods**
- Conclusion

Helium Leak Testing Applications and Methods

Common Production Leak Testing Methods

HELIUM
HYDROGEN
REFRIGERANTS
OTHERS

TRACER GAS

SNIFFING

MANUAL

MANUAL

Common Production Leak Testing Methods

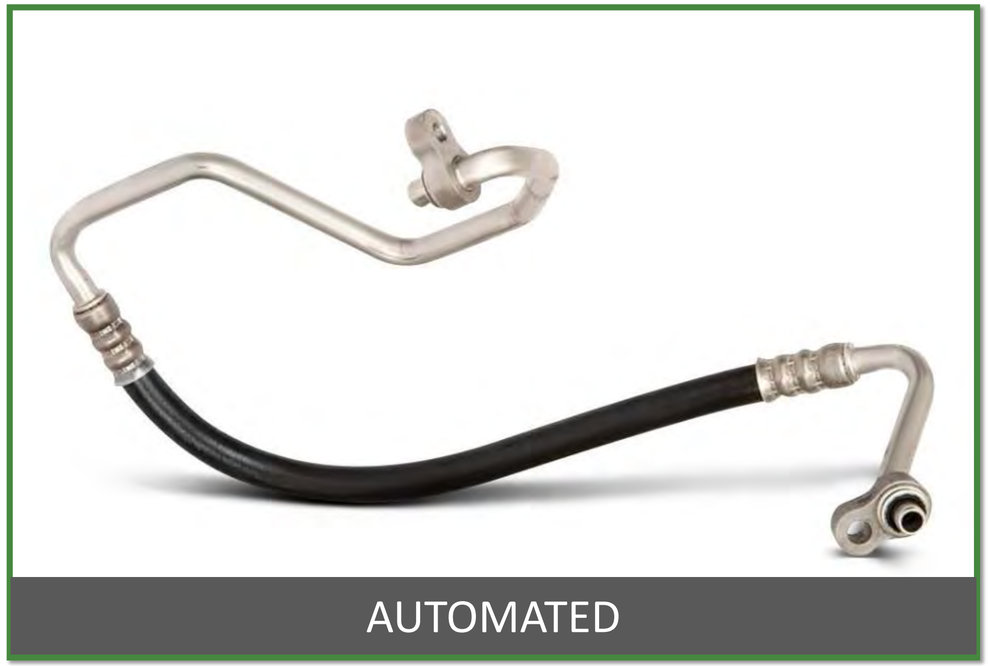
HELIUM
HYDROGEN
REFRIGERANTS
OTHERS

TRACER GAS

SNIFFING

MANUAL

AUTOMATED



AUTOMATED

Common Production Leak Testing Methods

HELIUM
HYDROGEN
REFRIGERANTS
OTHERS

TRACER GAS

- SNIFFING
  - MANUAL
  - AUTOMATED
- HARD VACUUM (chamber)
  - BOMBED

BOMBED

Common Production Leak Testing Methods

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HYDROGEN
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PRE-FILLED

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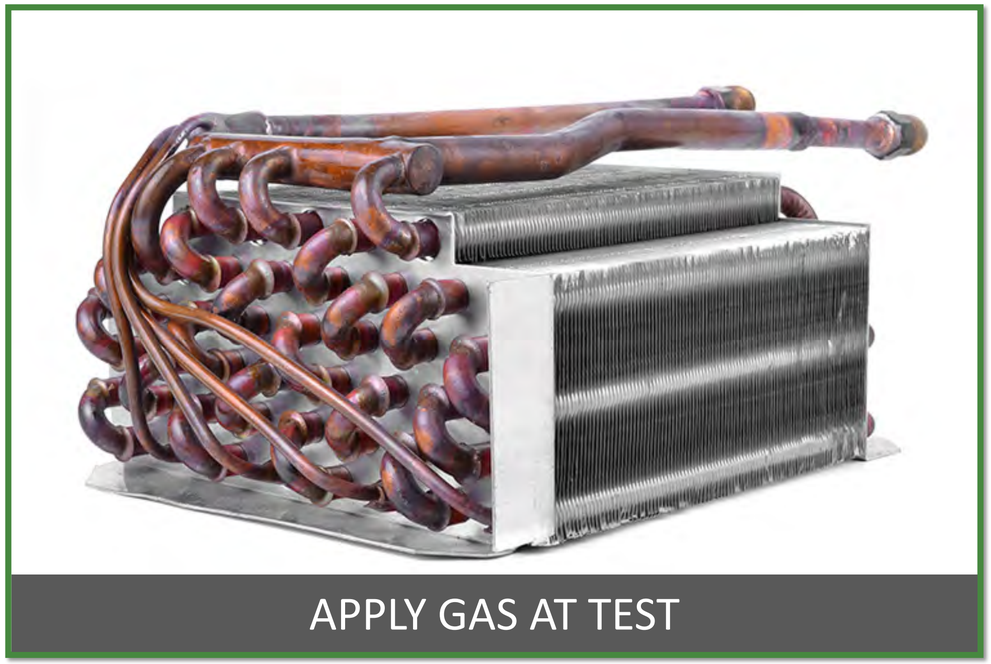
  - APPLY GAS AT TEST



APPLY GAS AT TEST

Common Production Leak Testing Methods

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- ACCUMULATION (chamber)
  - ATMOSPHERIC

ATMOSPHERIC

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AIR/NITROGEN
VACUUM

AIR

- VISUAL DETECTION
  - BUBBLE TESTING

BUBBLE TESTING

Common Production Leak Testing Methods

HELIUM
HYDROGEN
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AIR/NITROGEN
VACUUM

AIR

- VISUAL DETECTION
  - BUBBLE TESTING
- DIRECT FLOW
  - MASS FLOW

MASS FLOW

Common Production Leak Testing Methods

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AIR/NITROGEN
VACUUM

AIR

- VISUAL DETECTION
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- DIRECT FLOW
  - MASS FLOW
- PRESSURE CHANGE
  - VACUUM/ PRESSURE DECAY

VACUUM/PRESSURE DECAY

Common Production Leak Testing Methods

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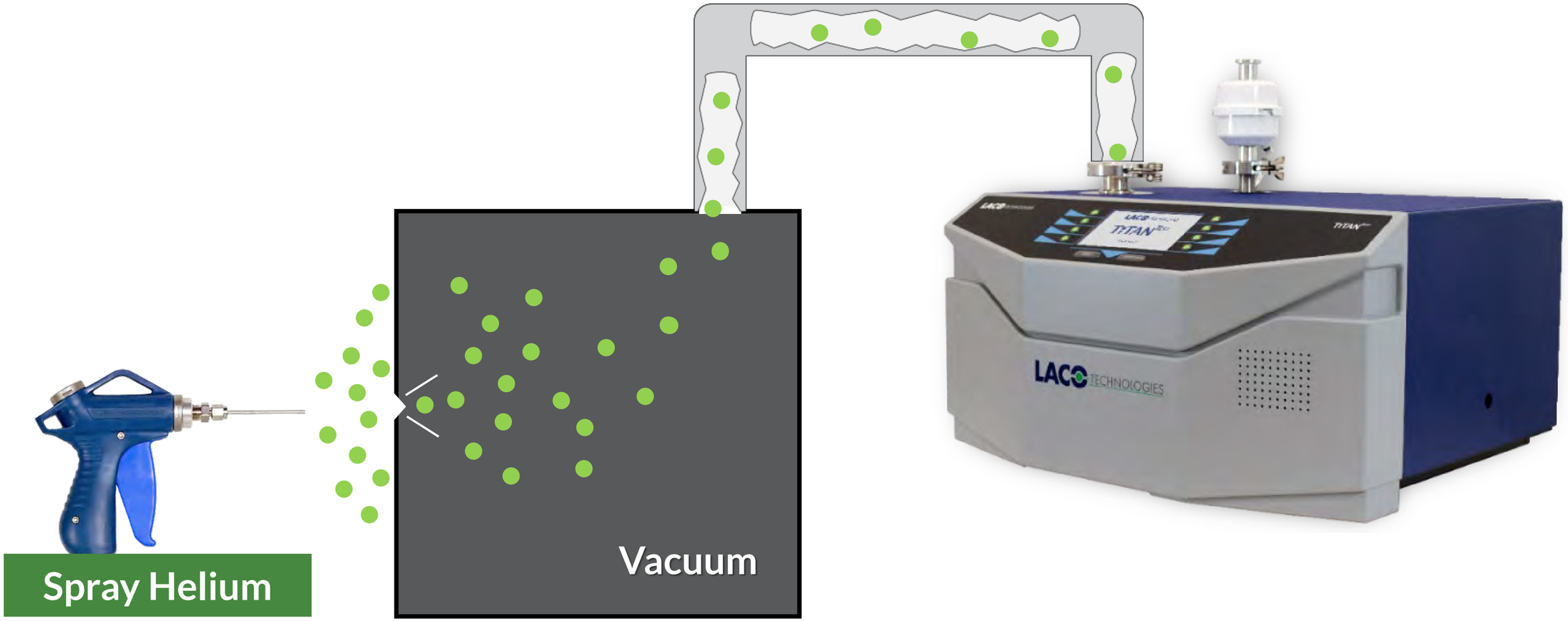
  - VACUUM/ PRESSURE DECAY
  - VACUUM/ PRESSURE DECAY (chamber)

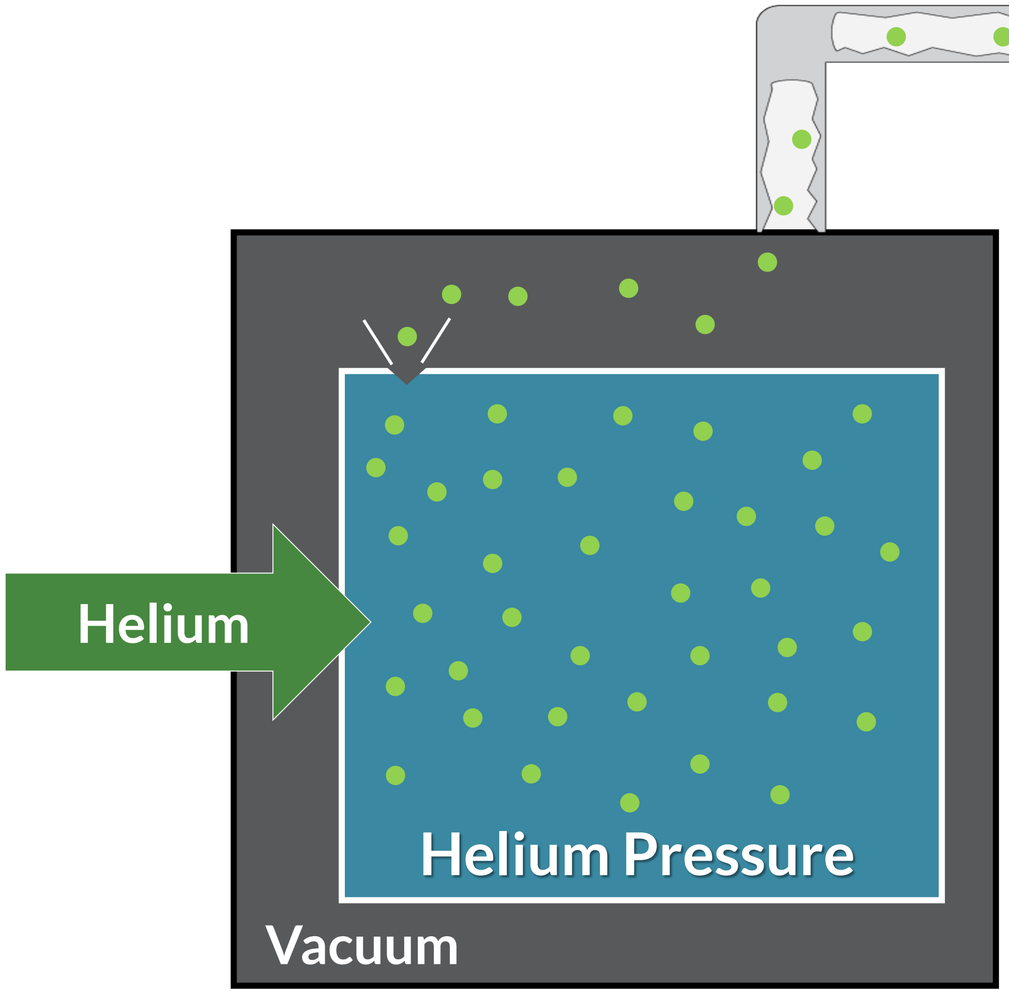
VACUUM/PRESSURE DECAY (chamber)

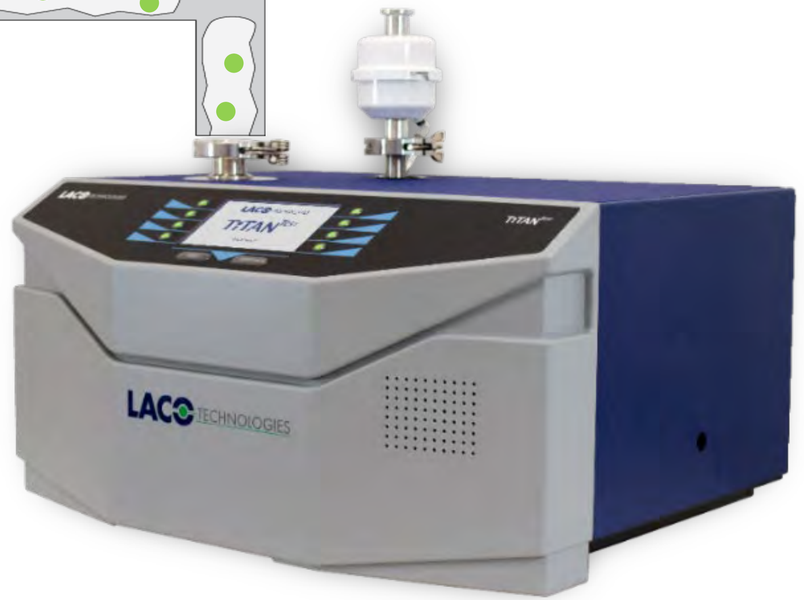
Hard Vacuum Test Outside-In | Helium Spray



Hard Vacuum Test Inside-Out

Helium Management Module



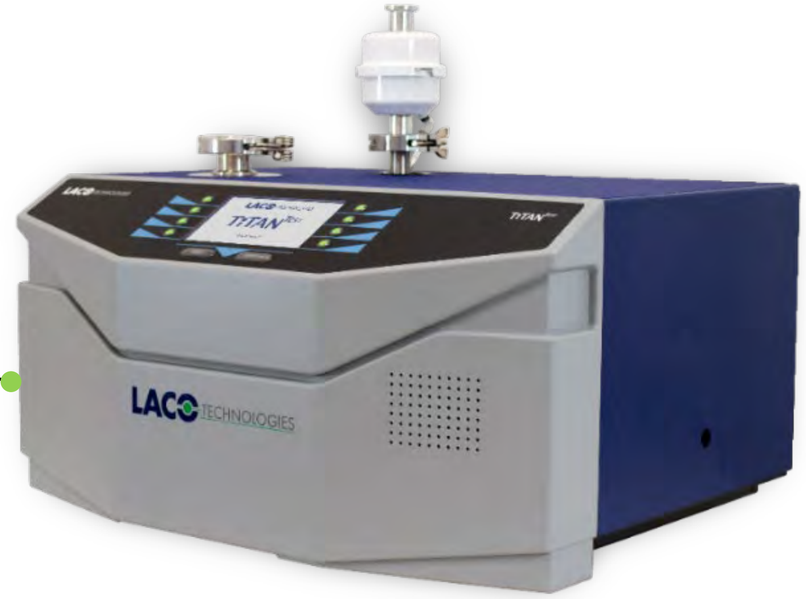


Helium Sniffing Test Principle

Helium Management Module

Helium

Helium Pressure



Accumulation Test Inside-Out

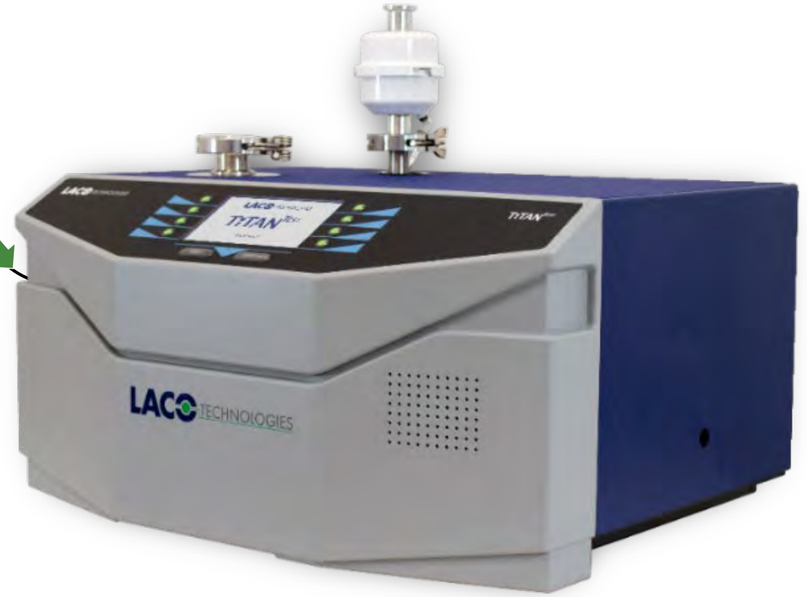
Helium Management Module

Helium

Gas Mixing Fan

Helium Pressure

Atmosphere



Why We Use Helium

Benefits of Helium Tracer Gas in Leak Testing

Helium Characteristics	Helium Benefits and Liabilities
Rare in the atmosphere (5 ppm = 0.005%)	**Allows detection of leaks to very low levels without background noise**
Inert (noble) gas	**Minimal safety concerns**
Atomic mass (AMU) of 4	**Easy detection via mass spectrometer with no interference from other gases**
Small gas molecule	**Leaks at a faster rate – ONLY through very small leak defects (molecular flow)**
Relatively high viscosity	**No benefit – leaks about 5% slower than Nitrogen (viscous flow)**
A non-renewable natural resource	**Possibility of eventual depletion of resources**

Benefits of Helium Leak Testing Methods

Helium Leak Test Method Characteristics	Helium Leak Testing Benefits and Liabilities
All positive characteristics of helium combined	**Provides the highest degree of sensitivity of any other method** (can find the smallest leaks – 1 million x smaller leaks than air leak testing)
Flexible test methods	**Allows for a variety of implementation methods into a production environment**
Both a global method as well as a tracer method	**Allows for global leak rate measurement** (unlike bubble testing), **and also allows for pinpointing of leak location** (unlike air leak testing)
Not temperature and volume dependent	**Compared to air leak testing, it is much more robust when dealing with temperature and volume variations during the actual test**
Higher instrumentation cost	**Can result in overall higher cost of a production leak test system – though the instrument cost is often less than 5% of total system cost**

Where Helium Comes from and Where It Is Used

Helium Production | Recovering | Refining

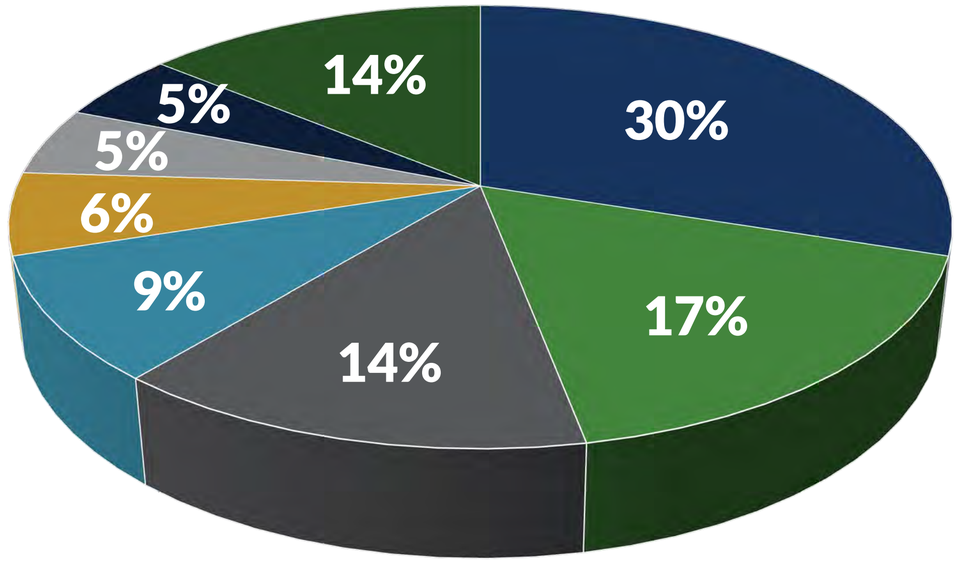
- Production
  - Produced over millions of years in the earth's crust by the slow and steady radioactive decay of terrestrial rock. Some helium remains trapped in the earth's crust, but much of it escapes the earth into the upper atmosphere
  - Cannot be manufactured at reasonable costs
- Recovery | Crude Helium
  - Recovered with Natural Gas in fields which have high enough helium concentration (up to about 7%)
- Refining | Purified Helium
  - Typically purified using cryogenic and membrane technologies. Purified to a variety of grades including balloon grade, industrial grade, and UHP grade

Helium | Where it is used…

In 2018, estimated domestic consumption of Grade-A helium was **39 million cubic meters** (1.4 billion cubic feet).

Most common uses/applications include:

- Magnetic Resonance Imaging (MRI) – **30%**
- Lifting Gas – **17%**
- Analytical & Laboratory – **14%**
- Welding – **9%**
- Engineering and Scientific – **6%**
- Leak Detection and Semiconductor –**5% each**
- Various other minor applications – **14%**



Source: USGS Mineral Commodity Summaries 2019

Helium Supply Issues and Trends

Helium Supply and Pricing | A Complex Issue

Helium supply and pricing are influenced by:

- US Government policy and laws
  - BLM will stop selling stockpiled helium by the US Government and by 2021 all assets will be sold and privatized
- Market demands
- Supply issues
  - Natural gas production trends
  - Gas plant shut-downs
  - Delays in new gas plant startups worldwide

Helium Supply and Pricing | A Complex Issue

Helium supply and pricing are influenced by:

- US Government policy and laws
- Natural gas production trends
- Gas plant shut-downs
- Delays in new gas plant startups worldwide

"The current shortage is the result of gradually diminished production capacity, the lack of new capacity coming into the market, and renewed growth in helium demand."

(Phil Kornbluth, Kornbluth Helium Consulting, LLC, February 2019)

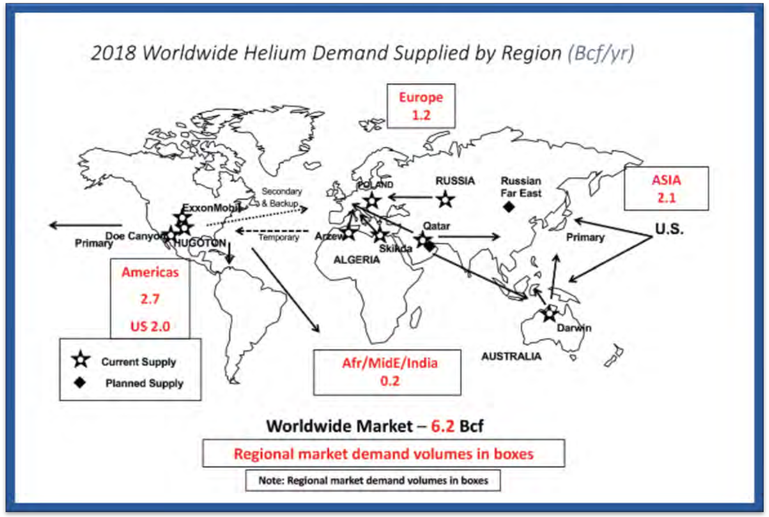
Helium Supply Forecasts | Helium Shortage 3.0

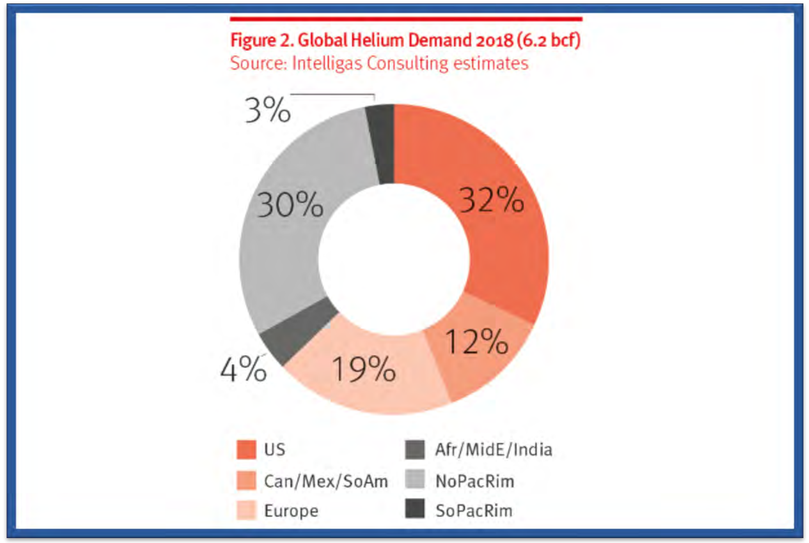
- Helium shortages began in **late 2017** to **early 2018**
- Helium shortages are expected to **subside into 2020** and supplies to return to **normal by end of 2020**

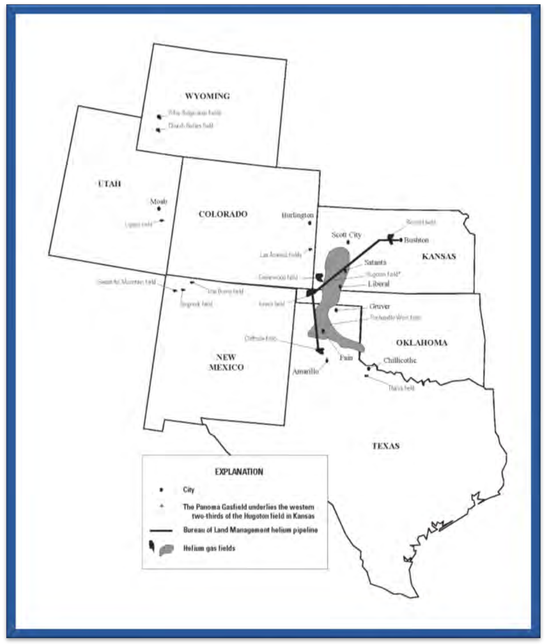
"The imbalance between helium supply and demand should be reduced considerably by the end of 2020."

(Phil Kornbluth, Kornbluth Helium Consulting, LLC, August 2019)

- Though the US is the primary producer of helium, international sources are **becoming a significant factor**







Helium Demand & Supply Map

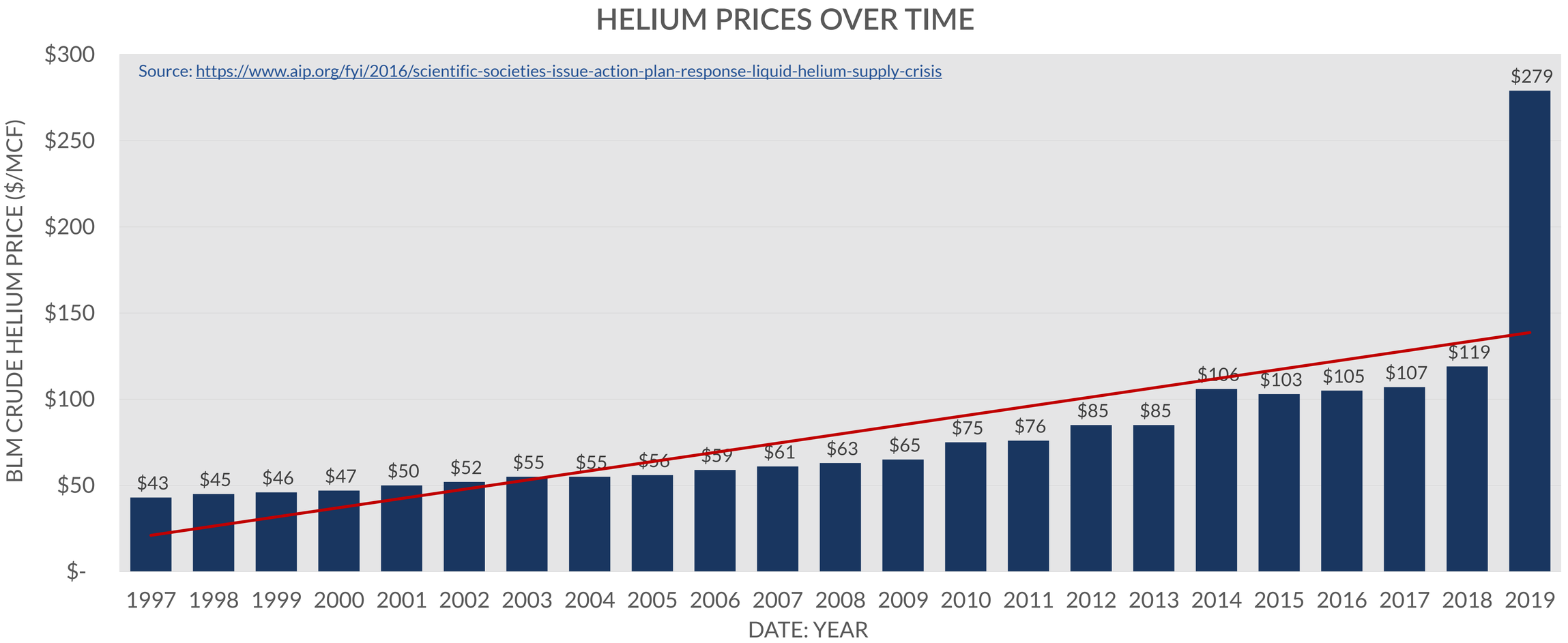
Are We Running Out of Helium?

- Worldwide annual production (2018): **160** million cubic meters*
- Worldwide known resources (2006): **>50,000** million cubic meters**
- At current demands: **>300** year supply of helium

NO

*Source: USGS Mineral Commodity Summaries, 2019 (excludes China)
** Includes reserves and known untapped resources

Helium Pricing Forecasts | Helium Shortage 3.0



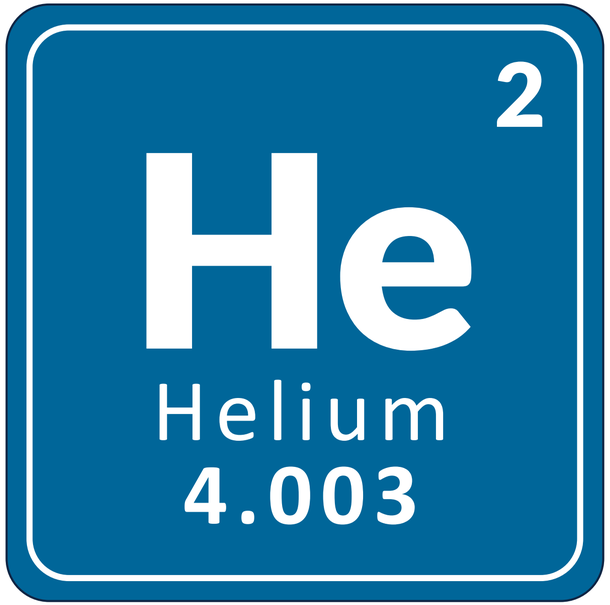
The price of Grade-A helium has risen by ~100% over the last 10 years

Helium Usage Strategies In Leak Testing

Overall Strategies | Two Options

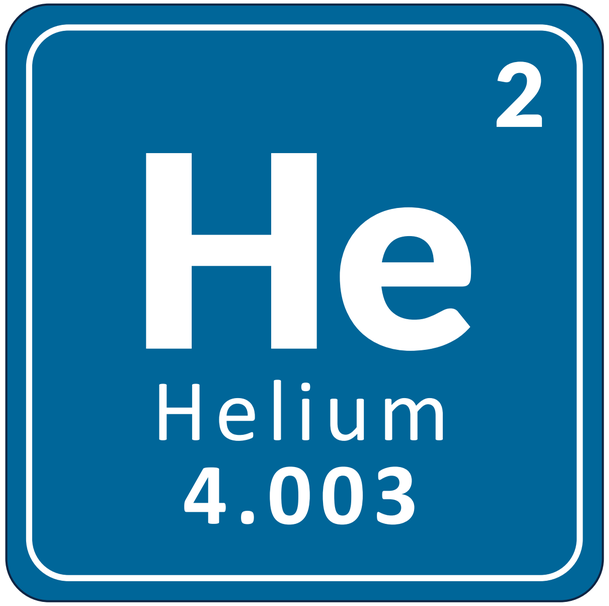
1. **Reduce** the amount of helium used

2. **Design** helium out of your process



Strategies | When You MUST Use Helium

- **REDESIGN** Test Criteria
  - **Lower pressures** or concentrations
  - **Loosen** leak rate **specifications**
- **RECLAIM** Helium
  - **Recover** and **reuse** helium back into your process
- **REDUCE** Waste



Strategies | Redesign the Test Criteria

NOTE: The following recommendations assume that you are **NOT** willing or able to loosen your leak rate requirements.

What if I lower the **HELIUM PRESSURE**?

- Ensure the lower test pressure will **not compromise** the test
- **Configure instrument** to detect a small leak rate of tracer gas in order to find equivalent size defect

Example:

- Reducing test pressure from **200 psig** to **100 psig** helium will save roughly **50%** helium
- A reject leak rate of 1×10^{-5} atmcc/sec at 200 psig would need to be lowered to roughly 3.2×10^{-6} atmcc/sec at 100 psig

Strategies | Redesign the Test Criteria

NOTE: The following recommendations assume that you are **NOT** willing or able to loosen your leak rate requirements.

What if I lower the **HELIUM CONCENTRATION?**

(diluting it with another gas, such as nitrogen, while keeping the same total test pressure)

- Premixed gas, gas blender, or mixing the gas inside the part is required
- To find an equivalent size defect, your instrument will need to be **configured to detect** a small leak rate of tracer gas

Example:

- Reducing concentration from **100%** to **10%** helium in nitrogen saves roughly **90%** helium, but will consume much more nitrogen and may require gas blending equipment
- A reject leak rate of 1×10^{-5} atmcc/sec at 100% helium would need to be lowered to roughly 1×10^{-6} atmcc/sec at 10% helium

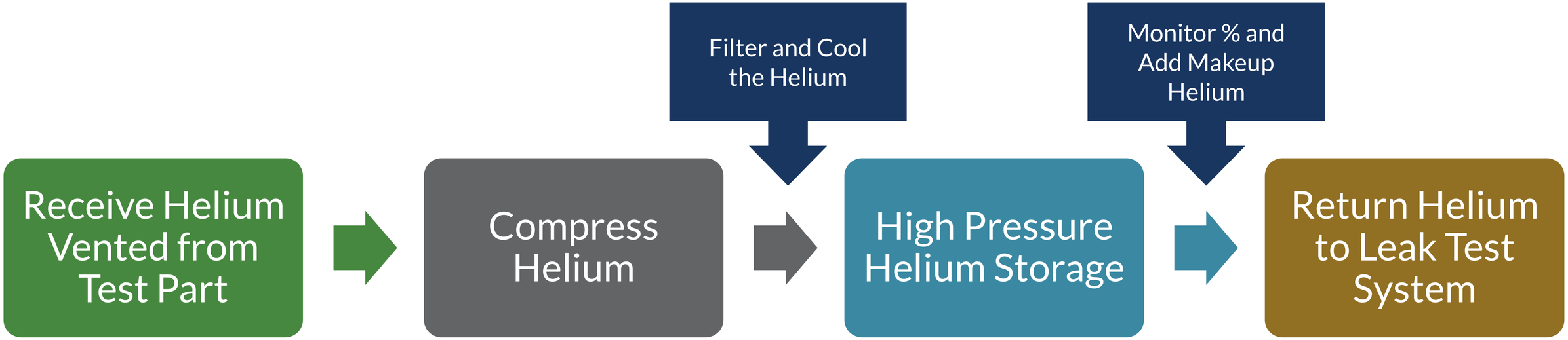
Strategies | Redesign the Test Criteria

- Reducing pressure or helium concentration will impact the size of leak you need to detect - **smaller**
- Detecting a smaller leak will require a **longer test time**
- Detecting a smaller leak **MAY** require **new or upgraded** system/equipment
- There is an associated **soft cost** for using less helium

Strategies | Helium Recovery

How does **HELIUM RECOVERY** work?

- Once the leak test is completed, the gas from the test part is **vented** into a low pressure helium recovery tank where it is **re-pressurized** for reuse



Strategies | Helium Recovery

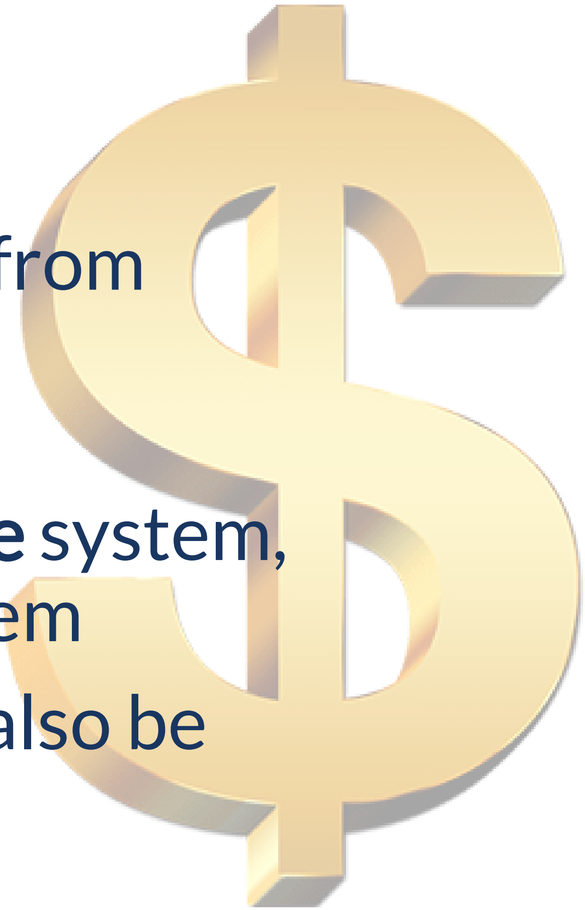
Requirements for **SUCCESSFUL HELIUM RECOVERY**

Requirement	Benefit
Pre-evacuate test part prior to filling with helium	Helium dilution and contamination by air will be minimized
High test pressures	Easier to recover a high percent of the overall helium without additional vacuum pumps to evacuate the helium from the part
Use near 100% helium	Recovering helium in applications where helium concentration is low wastes significant energy and equipment to also recover the other gas (nitrogen)
Relatively large helium usage	The ROI for helium recovery can be challenging for low usage applications

Strategies | Helium Recovery

What does it **COST** to recover helium?

- Helium recovery equipment can range in price from $**50,000 to over $500,000 USD**, depending on capacity and type of system
- Helium recovery equipment can be a **plant-wide** system, a **small collocated** system, or an **integrated** system
- Cost of ownership and efficiency (~90%) must also be considered



Strategies | Helium Recovery Trends

- As helium **prices continue to rise**, the ROI for helium recovery equipment will become easier to achieve
- As companies invest more in environmental initiatives, the **need for helium recovery equipment** will rise
- Because of **volatility** in helium supplies more companies are protecting themselves by implementing **helium recovery initiatives**

Strategies | Reducing Waste

Simple Strategies to **REDUCE HELIUM WASTE**

- **Drain** all helium from supply bottles
  - May require purchasing a gas pressure booster system
- **Minimize** excess test volumes (piping, hoses, valves, fixtures)
  - Many systems were not designed with helium efficiency in mind
- **Eliminate** external system helium leaks
  - Helium supply lines, as well as system helium piping, often have leaks

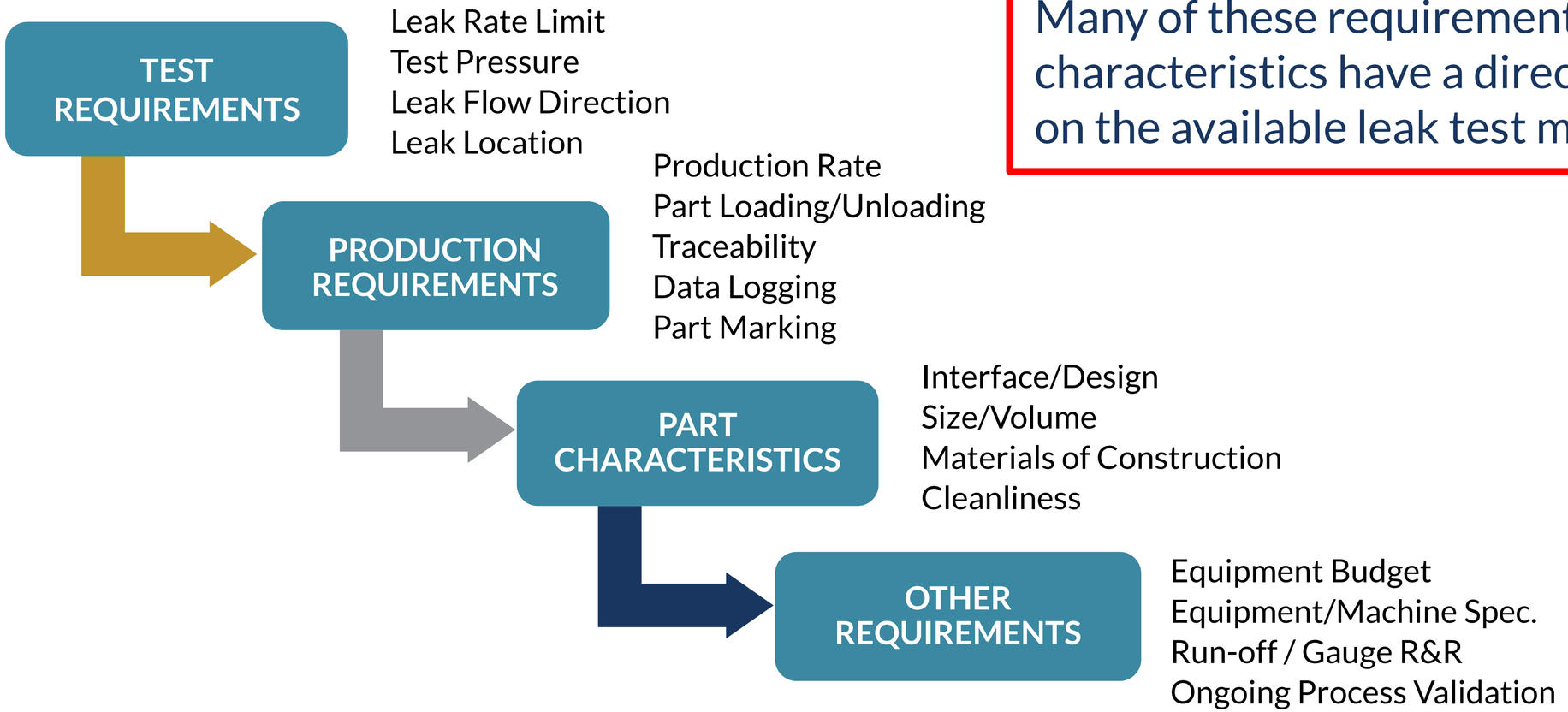
Substitutes for Helium

Strategies | Design Helium Out of the Process

What other gases or methods can be **substituted** for helium?

- Other Tracer Gases (chamber / sniffing)
  - Hydrogen (as forming gas – 5% H2 / 95% N2)
  - Others: refrigerants, sulfur hexafluoride, argon, nitrous oxide, and carbon dioxide
- Air Leak Test Methods
  - Pressure Decay
  - Mass Flow

Selecting a Leak Test Method



Many of these requirements and characteristics have a direct impact on the available leak test method.

Strategies | Design Helium Out of the Process

When considering an alternate leak testing method to helium, the most important criteria is often the **sensitivity of the proposed test** method.

Production Leak Test Methods | Typical Sensitivity

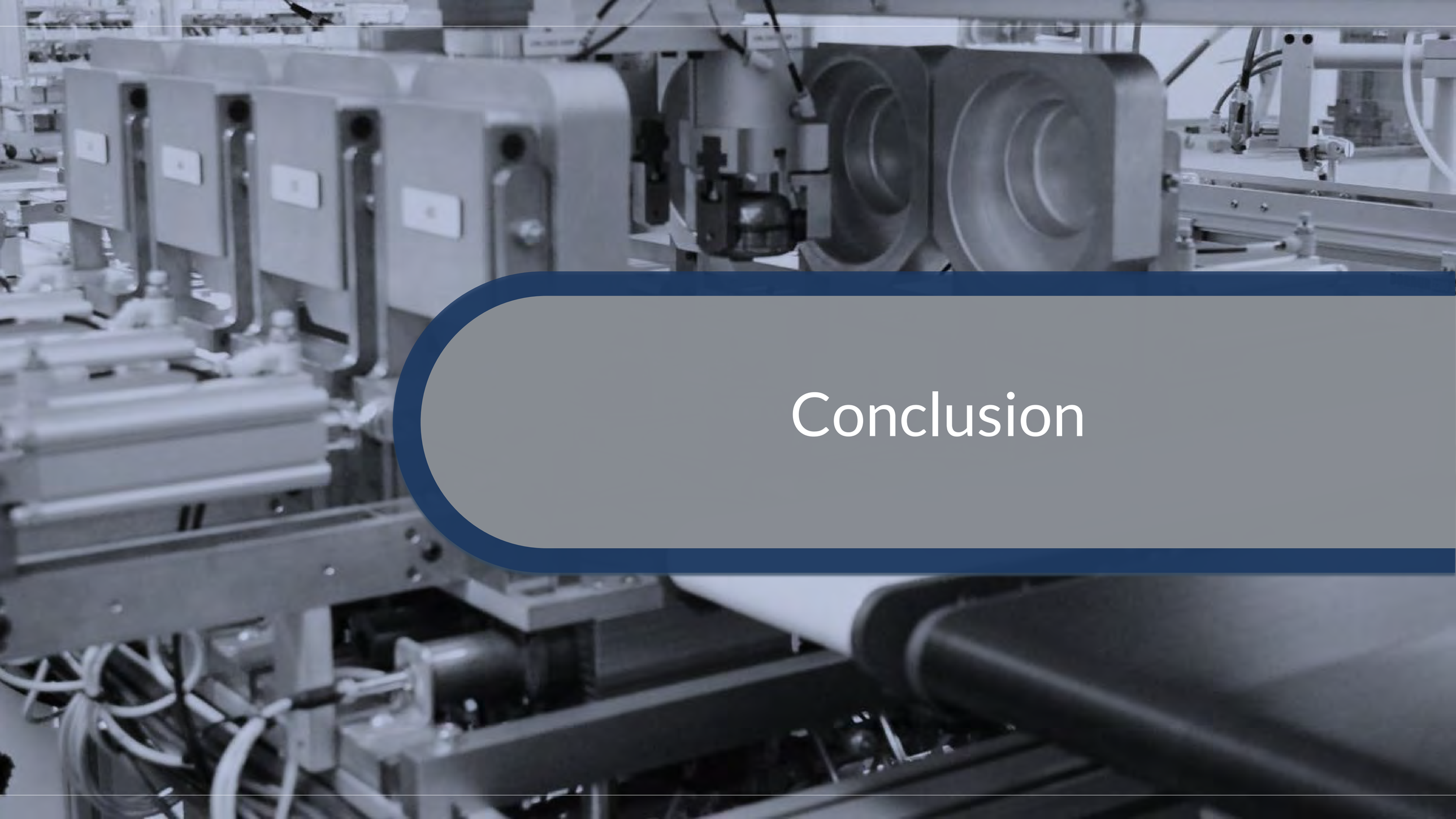
Proposed Test Gas	Test Method	Proposed Method Sensitivity (atm.cc/sec)*	Helium Sensitivity (atm.cc/sec)*
Hydrogen (5% in Nitrogen)	Sniffing	1×10^{-5}	1×10^{-6}
Hydrogen (5% in Nitrogen)	Chamber Accumulation	1×10^{-4}	1×10^{-5}
Hydrogen (5% in Nitrogen)	Chamber Hard Vacuum	1×10^{-5}	1×10^{-8}
Argon, CO2, Other	Chamber Hard Vacuum	1×10^{-4} to 1×10^{-6} (approx.)	1×10^{-8}
SF6, Refrigerants	Sniffing	1×10^{-5} to 1×10^{-7} (approx.)	1×10^{-7}
Air/Nitrogen	Pressure/Vacuum Decay (chamber / no chamber)	1×10^{-3}	1×10^{-8}
Air/Nitrogen	High Vacuum Decay – Chamber	1×10^{-5}	1×10^{-8}
Air/Nitrogen	Bubble Immersion	1×10^{-4}	1×10^{-8}

*Best **practical** sensitivity for most production leak testing applications.
May not be achievable in some applications and under some test conditions.

Strategies | Design Helium Out of the Process

Are there any great alternative leak test methods or gases to replace helium when **leak rate sensitivity** is critical?

- No other methods are **as sensitive** in production environments
- To completely remove helium there's **almost always** a compromise in sensitivity or test cycle time



Conclusion

Conclusion

- The volatility of the helium market **is likely to continue through 2020** and may raise its head again years down the road
- Despite volatile helium supplies and pricing, **we are NOT running out of helium**
- There are many strategies that **can reduce helium consumption** and costs in leak testing
- There are **few options for eliminating helium** without making other compromises

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