

# Depressurization: detecting a leak, isolating a volume and preserving a refuge

## Guiding question

Concrete → flows → sensors → calculation → failure → refuge.

## Course map

The real phenomenon → Vocabulary and problem boundary → Course-specific system view → Mathematical relationship and reading the symbols → Worked calculations and interpretation

## 1 — The real phenomenon

Pressure loss can be slow or rapid. Sensors track total pressure, rate of decay and sometimes acoustics or flow. A survival architecture limits volumes, provides isolation hatches and valves, preserves gas reserves and defines a pressurized refuge. Available time depends on volume, pressure, leak size and flow regime; simple calculations are only for reasoning before detailed compressible-flow models.

The guiding question is: How do you buy time when a wall, seal or penetration no longer holds pressure? Reasoning starts with the physical or operational function before introducing the mathematical relationship. The goal is not to accumulate terminology, but to know which quantity changes, why it changes and what becomes hazardous when it leaves its domain. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the first task here is therefore to identify the mechanism specific to this subject before searching for an equation or reference value.

## 2 — Vocabulary and problem boundary

In “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, distinguish the phenomenon, available measurement, any command, the margin and the success criterion. The calculation boundary states what is included and excluded; without that boundary, a percentage, mass or time may be mathematically correct but wrong as an engineering conclusion. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the chosen boundary also states what would otherwise be double-counted or omitted from a mission budget. cabin pressure, leak rate, smoke, combustion products, temperature, compartment differential and valve state an unlocated leak, a bulkhead that fails to close, hidden fire or suppression that degrades atmosphere detection tests, compartment isolation, controlled pressure decay and timed crew scenarios

## Equation - evidence - decision

$$pV = nRT ; \text{taux} \approx \Delta p / \Delta t$$

Failure to test: The reference failure is not a vague “broken component.” For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, test in particular an unlocated leak, a bulkhead that fails to close, hidden fire or suppression that degrades atmosphere. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

**Depressurization: detecting a leak, isolating a volume and preserving a refuge****3 — Course-specific system view**

This lesson does not reuse one generic picture for every subject. The system view follows cause → measured quantity → decision or physical response → limit for “Depressurization: detecting a leak, isolating a volume and preserving a refuge”. The English text remains fully equivalent while large translated illustrations are intentionally deferred until their dedicated artwork is supplied. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the system view must expose inputs, outputs, measured quantity and the consequence of drift without relying on a generic module diagram.

**4 — Mathematical relationship and reading the symbols**

Read aloud : for an ideal gas, pressure  $p$  times volume  $V$  equals amount  $n$  times gas constant  $R$  times temperature  $T$ ; a simple rate can be estimated as pressure change divided by time.

Before substituting numbers, write the unit of every term, state whether the relationship is a physical law, approximation or project indicator, and check dimensional consistency. This is especially important here because “Depressurization: detecting a leak, isolating a volume and preserving a refuge” combines quantities that do not all have the same evidence status. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, this relationship is chosen because of the phenomenon under study; a different dominant quantity would require a different equation or model.

**5 — Worked calculations and interpretation**

101 – 99 = 2 kPa in 10 min → 0.2 kPa/min in a linear approximation

from 99 to 70 kPa at 0.2 kPa/min →  $29/0.2 = 145$  min, only if rate stayed constant

12 kg + 12 kg = 24 kg; separated bottles reduce single-loss risk

1. 1. Measured decay 101 – 99 = 2 kPa in 10 min → 0.2 kPa/min in a linear approximation Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Depressurization: detecting a leak, isolating a volume and preserving a refuge”.

2. 2. Simplified time from 99 to 70 kPa at 0.2 kPa/min →  $29/0.2 = 145$  min, only if rate stayed constant Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Depressurization: detecting a leak, isolating a volume and preserving a refuge”.

3. 3. Gas reserve 12 kg + 12 kg = 24 kg; separated bottles reduce single-loss risk Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Depressurization: detecting a leak, isolating a volume and preserving a refuge”.

**Operational table**

**Phenomena / sections:** 3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation

**Relationship to revisit:**  $pV = nRT$  ;  $\text{taux} \approx \Delta p / \Delta t$

**Expected decision:** measure → compare with margin → choose nominal, degraded or stop

**Check before continuing**

Explain without rereading: 3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation. State one measured quantity, one margin and one possible decision.

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6 — What the formula does not contain

The relationship “ $pV = nRT$  ;  $\text{taux} \approx \Delta p/\Delta t$ ” does not by itself contain all of “Depressurization: detecting a leak, isolating a volume and preserving a refuge”. It does not automatically tell us whether a sensor is valid, a structure is aging, a resource is accessible, a command arrives in time or a secondary failure removes margin. The example  $101 - 99 = 2 \text{ kPa}$  in  $10 \text{ min} \rightarrow 0.2 \text{ kPa/min}$  in a linear approximation therefore remains a local calculation rather than a complete architecture.

To make the model useful, explicitly add the quantities that dominate this subject: cabin pressure, leak rate, smoke, combustion products, temperature, compartment differential and valve state. We can then ask which variation truly changes the result, which is negligible and which forces an architectural change. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, this model limitation states exactly what a correct calculation still cannot establish about the real system.

7 — Instrumentation, observability and data quality

For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, observability relies on cabin pressure, leak rate, smoke, combustion products, temperature, compartment differential and valve state. Each datum has a unit, acquisition rate, uncertainty, timestamp and validity domain. A value arriving without context can be more dangerous than no measurement because it creates unjustified confidence.

Consistency is checked with at least one independent piece of information when the function is critical. A trend, physical balance or second measurement principle helps distinguish a real system change from a drifting sensor. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the selected instrumentation must distinguish a real physical change from sensor drift or a bad state estimate.

8 — Phenomenon-specific failures and recovery

The reference failure is not a vague “broken component.” For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, test in particular an unlocated leak, a bulkhead that fails to close, hidden fire or suppression that degrades atmosphere. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

The degraded mode must be defined before failure: minimum function, allowable duration, consumed stock, crew action, abort condition and return-to-nominal criterion. That sequence is topic-specific and cannot be replaced by one universal paragraph about redundancy. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the degraded mode is defined around the minimum function

Operational table

|                          |                                                                                                                                             |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Phenomena / sections:    | 6 — What the formula does not contain ; 7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery |
| Relationship to revisit: | $pV = nRT$ ; $\text{taux} \approx \Delta p/\Delta t$                                                                                        |
| Expected decision:       | measure → compare with margin → choose nominal, degraded or stop                                                                            |

Check before continuing

Explain without rereading: 6 — What the formula does not contain ; 7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery. State one measured quantity, one margin and one possible decision.

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9 — NASA / reference case

The reference case is selected from ECLSS, NASA-STD-3001 or human-analog evidence according to the topic. The goal is not to copy the ISS onto Mars, but to identify what has been demonstrated, what is environment-dependent and what still requires qualification for a mission without rapid resupply.

The case is used only within what it actually demonstrates. Flight measurement, human-system standard, component test and architecture study are different kinds of evidence; the text therefore states what is observed, calculated, simulated or still prospective. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the cited NASA case is used as targeted evidence for this phenomenon and is never turned into one universal Mars architecture.

10 — Architecture trade

A good solution for “Depressurization: detecting a leak, isolating a volume and preserving a refuge” does not maximize one metric. Compare nominal performance, mass, energy, simplicity, maintenance, crew time, common dependencies and recoverability. An option that improves from 99 to 70 kPa at 0.2 kPa/min → 29/0.2 = 145 min, only if rate stayed constant can still be rejected if it makes failure detection or repair much harder.

The trade is recorded together with its assumptions. If environment data, mass or mission cadence changes, we know which conclusions must be recomputed instead of silently preserving an obsolete choice. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the trade is evaluated against the interfaces actually touched by this subject rather than a generic list of desirable qualities.

11 — Demonstration, testing and success criteria

The evidence strategy for “Depressurization: detecting a leak, isolating a volume and preserving a refuge” combines detection tests, compartment isolation, controlled pressure decay and timed crew scenarios. Every test records exact hardware, software, configuration, environment, tolerances and success criterion. A successful demonstration outside the mission domain does not replace qualification inside it.

Evidence grows by levels: analytical relationship, simulation, component, subsystem, integrated system, duration and failure. This hierarchy prevents one spectacular test from being presented as validation of the whole mission. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, demonstration must reproduce the constraints that make this phenomenon difficult; a spectacular test outside the mission domain is insufficient.

Operational table

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|--------------------------|--------------------------------------------------------------------------------------------------------|
| Phenomena / sections:    | 9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria |
| Relationship to revisit: | $pV = nRT$ ; $\text{taux} \approx \Delta p / \Delta t$                                                 |
| Expected decision:       | measure → compare with margin → choose nominal, degraded or stop                                       |

Check before continuing

Explain without rereading: 9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria. State one measured quantity, one margin and one possible decision.

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12 — Decision exercise

Situation: revisit “Depressurization: detecting a leak, isolating a volume and preserving a refuge” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable.

Situation: revisit “Depressurization: detecting a leak, isolating a volume and preserving a refuge” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable. Expected answer: recompute the relationship, identify remaining margin, check whether observability is still adequate, and decide whether degraded operation remains acceptable. Multiplying by 1.2 is not enough if the variation also changes interfaces or limits.

13 — What to retain without over-generalizing

14 — Topic-specific primary sources

These references directly document the phenomenon, technology or human constraint addressed in this lesson. They do not by themselves define an official Mars architecture. For “Depressurization: detecting a leak, isolating a volume and preserving a refuge”, the bibliography is deliberately targeted to this page so that readers can trace each claim back to the relevant primary document.

Topic-specific primary sources

NASA — Spaceflight Human-System Standard, Volume 2 - <https://www.nasa.gov/reference/nasa-std-3001v2/>

NASA NTRS — Advanced Exploration Systems Life Support Systems Project Overview - <https://ntrs.nasa.gov/citations/20210015025>

NASA NTRS — Life Support Baseline Values and Assumptions Document - <https://ntrs.nasa.gov/citations/20210024855>

Operational table

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|--------------------------|--------------------------------------------------------------------------------------------------------------|
| Phenomena / sections:    | 12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources |
| Relationship to revisit: | $pV = nRT$ ; $\text{taux} \approx \Delta p / \Delta t$                                                       |
| Expected decision:       | measure → compare with margin → choose nominal, degraded or stop                                             |

Check before continuing

Explain without rereading: 12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources. State one measured quantity, one margin and one possible decision.