# Leaf Chamber (LC-7000)

**Vapor Pressure Deficit & Boundary Layer Conductance**

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# Vapor Pressure Deficit Stability of LC-7000

Here we assesse the stability of Vapor Pressure Deficit (VPD) within the CredoSense leaf chamber during measurements. An analysis of 300 leaf samples shows that the change in VPD for each measurement typically falls between $-0.15$ kPa and $+0.15$ kPa, with an average change of $-0.01$ kPa. This indicates that the leaf chamber maintains very good stability of VPD for each measurement.

## Importance of maintaining VPD stability

Maintaining VPD stability during leaf gas exchange measurements is crucial for obtaining accurate and reliable data in plant physiology studies:

- **Consistent transpiration rates:** VPD directly influences the rate of transpiration in plants. A stable VPD ensures consistent transpiration rates during measurements, which is essential for accurately assessing water loss and plant water relations.
- **Accurate stomatal conductance measurements:** Stomatal behavior is sensitive to changes in VPD. Fluctuations can cause stomata to open or close, affecting gas exchange rates. Maintaining a stable VPD allows for precise measurements of stomatal conductance and photosynthetic rates.
- **Controlled experimental conditions:** Consistency in environmental parameters like VPD ensures that any observed changes in plant responses are due to experimental treatments rather than unintended environmental variability.
- **Minimizing measurement errors:** VPD fluctuations can introduce noise and variability in the data. Stable VPD conditions reduce measurement errors and improve the repeatability and reliability of results.

## Accepted range for VPD stability

A VPD fluctuation within $\pm0.1$ to $\pm0.15$ kilopascals (kPa) is generally considered acceptable for most physiological measurements. This range minimizes the impact of VPD on plant responses during the measurement period. An average change close to zero indicates excellent VPD stability. This level of control is ideal for high-precision studies.

## Calculation of VPD

Vapor Pressure Deficit (VPD) reflects the difference between the amount of moisture in the air and how much moisture the air can hold when it is saturated. It is calculated using the following steps:

- Record the leaf temperature ($T$) in degrees Celsius (°C).
- Calculate the Saturation Vapor Pressure ($e_s$): $0.6108 \times \exp\left(\frac{17.27 \times T}{T+237.3}\right)$
- Record the relative humidity (RH) as a percentage (%) within the chamber.
- Calculate the Actual Vapor Pressure ($e_a$) = $e_a \times \left(\frac{RH}{100}\right)$
- Calculate the VPD: $e_s - e_a$

## Determination of VPD stability

For each one-minute measurement session, consisting of 60 data points (collected at 1 Hz), the VPD stability is calculated as the change in VPD from the average of the first 10 VPD measurements. The calculation steps are as follows:

- Record VPD measurements: Let's denote the VPD measurements as $VPD_i$ for $i = 1, 2, \ldots, 60$.
- Calculate initial average VPD by taking the average VPD of the first 10 measurements: $\overline{VPD}\text{initial} = \frac{1}{10} \sum i = 1^{10} VPD_i$.
- For each observation within each 60s, calculate the change in VPD from the initial average: $\Delta VPD_i = VPD_i - \overline{VPD}_{\text{initial}}$, for $i = 1, 2, 3, \ldots, 60$.
- The VPD stability is assessed by analyzing the values of $\Delta VPD_i$ over the measurement period. A small range of $\Delta VPD_i$ indicates high stability.

### 0.1 VPD stability of LC-7000

The change in VPD for individual measurements ranged from $-0.1$ kPa to $+0.1$ kPa. The mean VPD change across all samples was $-0.01$ kPa. The majority of measurements clustered around zero change, indicating high stability in the VPD maintained by the leaf chamber.

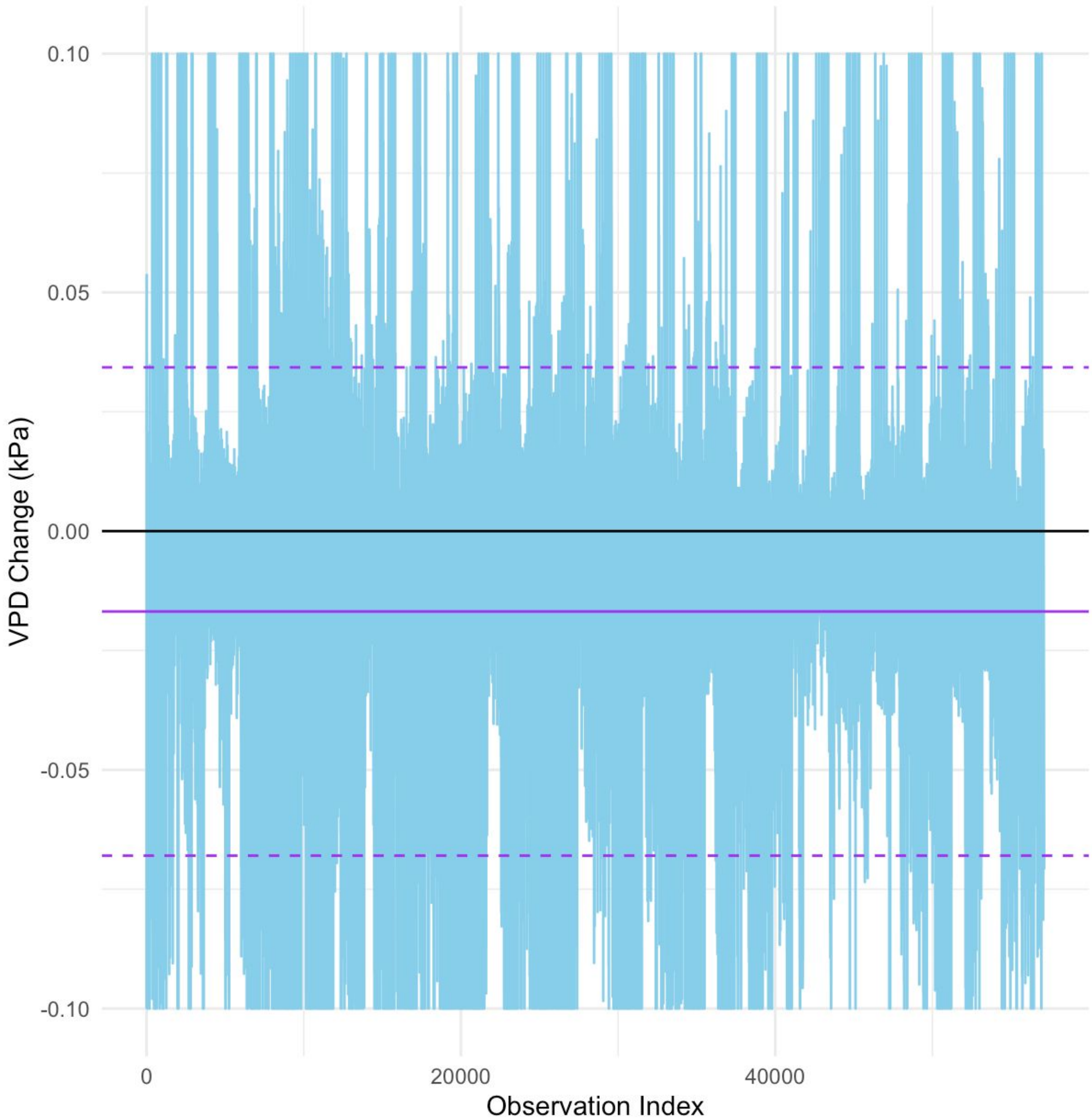


**Figure 1:** Showing the distribution of VPD changes for the 300 leaf samples measured. The majority of changes are centered around zero, indicating minimal fluctuation.

The CredoSense leaf chamber demonstrates excellent stability in maintaining VPD during measurements. With changes predominantly within $\pm 0.15$ kPa and an average change of $-0.01$ kPa across 300 samples, the chamber effectively provides a consistent environment. This stability is crucial for accurate and reliable plant physiological measurements.

# Boundary Layer Conductance to Water Vapor

Boundary layer conductance to water vapor ($g_{bw}$) represents the rate at which water vapor diffuses through the boundary layer of air directly surrounding a leaf. This boundary layer is a thin layer of still or slow-moving air that significantly influences gas exchange between the leaf surface and the surrounding atmosphere. The conductance of this layer affects the exchange of water vapor, $CO_2$, and other gases between the leaf and the atmosphere, and thus directly impacts transpiration rates and photosynthesis.

The CredoSense leaf chamber is designed to measure gas exchange under controlled conditions, where the boundary layer conductance plays a crucial role in obtaining accurate results. Ensuring accurate measurement of ($g_{bw}$) is essential for understanding the plant's water use efficiency and response to environmental conditions.

## Importance of boundary layer conductance

- **Control of transpiration rates**: $g_{bw}$ regulates the diffusion of water vapor from the leaf interior to the atmosphere. A higher conductance means that water vapor can exit the leaf more freely, leading to increased transpiration rates.
- **Impact on stomatal conductance measurements**: Stomatal conductance, another critical measure in plant physiology, is affected by the boundary layer. A well-characterized ($g_{bw}$) helps separate the effects of the boundary layer from the stomatal conductance, yielding more accurate insights into plant water regulation.
- **Influence on photosynthesis**: Gas exchange, including $CO_2$ uptake for photosynthesis, is affected by the boundary layer. Stable $g_{bw}$ values help maintain reliable photosynthesis measurements, ensuring that environmental factors, rather than measurement artifacts, drive any observed variation.

## Calculation of boundary layer conductance

The boundary layer conductance in the CredoSense chamber can be calculated using an empirical formula modified from the Licor chamber:

$$g_{bw} = c_0 + c_1 \cdot f + c_2 \cdot f \cdot s^2 + c_3 \cdot s \cdot f + c_4 \cdot f^2$$

where:

- $g_{bw}$ = Boundary layer conductance to water vapor (mol m$^{-2}$ s$^{-1}$),
- $f$ = Factor based on fan speed and atmospheric pressure,
- $s$ = Leaf area (cm$^2$),
- $c_0, c_1, c_2, c_3, c_4$ = Empirical coefficients specific to the CredoSense chamber, which are slightly modified from Licors empirical values.

**Given parameters**:

- Atmospheric pressure, $P_a = 998.914\,\text{hPa}$ (from actual measurements of 300 leaves),
- Chamber pressure, $P_o = 998.25\,\text{hPa}$ (from actual measurement of 300 leaves),
- Fan speed, RPM = 5500,
- Leaf area, $s = 11.55\,\text{cm}^2$,
- Empirical coefficients for the CredoSense chamber:
  - $c_0 = 0.578$,
  - $c_1 = 0.523$,
  - $c_2 = 0.004$,
  - $c_3 = -0.062$,
  - $c_4 = -0.006$.

## Step-by-Step calculation of $f$ and $g_{bw}$

### 1. Calculate $f$:

The factor $f$ is derived based on fan speed (RPM) and the ratio of atmospheric pressures:

$$f = \frac{\text{Fan Speed (RPM)} \times P_a}{1000 \times P_o}$$

Substituting values:

$$f = \left(\frac{5500}{1000}\right) \times \frac{998.914}{998.25} = 5.5 \times 1.000665 = 5.50366$$

**2. Calculate $g_{bw}$:**

Substitute the values of $f$ and $s$ into the empirical formula:

$$g_{bw} = c_0 + c_1 \cdot f + c_2 \cdot f \cdot s^2 + c_3 \cdot s \cdot f + c_4 \cdot f^2$$

Breaking down each term in the formula:

$$\begin{aligned}
1^{st} \text{ term:} &\quad c_0 = 0.578 \\
2^{nd} \text{ term:} &\quad c_1 \cdot f = 0.523 \times 5.5037 = 2.87942 \\
3^{rd} \text{ term:} &\quad c_2 \cdot f \cdot s^2 = 0.004 \times 5.5037 \times (11.55)^2 = 0.004 \times 5.50366 \times 133.4025 = 2.94 \\
4^{th} \text{ term:} &\quad c_3 \cdot s \cdot f = -0.062 \times 11.55 \times 5.50366 = -3.934 \\
5^{th} \text{ term:} &\quad c_4 \cdot f^2 = -0.006 \times (5.50366)^2 = -0.18108
\end{aligned}$$

Summing these terms gives:

$$g_{bw} = 0.578 + 2.87942 + 2.94 - 3.934 - 0.18108 = 2.08 \,\text{mol m}^{-2}\text{s}^{-1}$$

Thus, the boundary layer conductance ($g_{bw}$) is calculated to be approximately **2.08 mol m$^{-2}$ s$^{-1}$**.

## Commonly accepted values for boundary layer conductance

For reference, in similar setups using a Licor 6800 chamber, the boundary layer conductance values typically range around **1.979 mol m$^{-2}$ s$^{-1}$**. The CredoSense chamber provides a comparable $g_{bw}$ value, reflecting its efficient design in maintaining stable boundary layer conditions. Standard values for $g_{bw}$ can vary depending on chamber design, fan speed, and leaf area, but values around 1.8 to 2.0 mol m$^{-2}$ s$^{-1}$ are generally considered reliable for accurate gas exchange measurements in similar chamber configurations.