

While the C-sense is a relatively easy instrument to use, there are certain characteristics of operation that should be understood in order to measure pCO<sub>2</sub> as accurately and precisely as possible. Equilibration time and warm-up time are the two which seem to cause the most confusion when measuring pCO<sub>2</sub>.

Equilibration time is defined as the time required for the ambient concentration of carbon dioxide gas to equilibrate across the C-sense membrane. Often the equilibration time is stated as a T63 level, or the time it takes for 63% of the equilibration to occur. The specified T63 level for the C-sense is 4 minutes.

For example, if a C-sense is measuring a pCO<sub>2</sub> concentration of 500 ppm in air and it is submerged in water that has a pCO<sub>2</sub> concentration of 1200 ppm, the value of pCO<sub>2</sub> measured by the C-sense will be 63% of the difference between initial and final values of pCO<sub>2</sub> after 4 minutes.

Initial pCO<sub>2</sub> = 500 ppm  
Final pCO<sub>2</sub> = 1200 ppm  
pCO<sub>2</sub> difference between initial and final concentrations = 700 ppm  
63% of 700 ppm = 441 ppm  
Measured pCO<sub>2</sub> after 4 minutes = 991 ppm

There are multiple factors that affect equilibration time, one of the most significant being flow speed across the membrane. For this reason, the C-sense can be outfitted with a water-pumped head to pump water across the membrane. For reference, the total equilibration time for the C-sense is approximately 15 minutes. That value can be reduced to 12 minutes using the water-pumped head (PN 2400-700). If the water-pumped head is not a possibility, the user needs to be aware of the naturally occurring flow and how that will effect equilibration times. If there is little to no flow in the water being measured, equilibration can take significantly longer than the stated 15 minutes. Another factor affecting equilibration time is the amount of bio-fouling on the C-sense membrane. Accumulation of bio-fouling has two potential though competing effects on measuring pCO<sub>2</sub> with the C-sense. The presence of the accumulation can increase the equilibration time by impeding the transfer of gasses. Alternatively, the organisms can respire CO<sub>2</sub>, artificially elevating the CO<sub>2</sub> concentration measured by the C-sense. Turner Designs offers accessories for the C-sense that help reduce the effects of bio-fouling. A Copper Antifouling Guard (P/N 2400-507) can be installed on the sensor head outside the membrane to prevent organisms from growing on the instrument head. The Water-Pumped Head also discourages bio-accumulation by limiting the amount of light that reaches the C-sense membrane.

Warm-up time of the C-sense instrument, between 45 seconds and 3 minutes, is specific to the operation of the NDIR (Non-Dispersive Infrared) detector. The measurement provided by the NDIR is used as a proxy for pCO<sub>2</sub> concentration. This measurement is most accurate when the heat generated by the detector dissipates into the surroundings resulting in a stable temperature. In order to prevent a measurement before the detector stabilizes, the C-sense will not output data for the first 45 seconds after power is applied. Unlike the equilibration time, warm-up time is dependent on the instrument being powered.

Understanding the equilibration and warm-up time of all pCO<sub>2</sub> sensors is critical if a user expects to measure the concentration of CO<sub>2</sub> precisely and accurately. A few of the most significant factors affecting the performance of the C-sense are discussed here but there are many other factors that may need to be considered depending on your sampling environment. Our C-sense FAQ section contains a lot of pertinent information and may help answer some of your questions.