Correcting for Changes in O₂ Concentration in the LI-6400 Photosynthesis System

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ABSTRACT
In this study, we characterized the effects of oxygen concentration on the LI-6400 IRGA and flow meter. In the worst case (removing all oxygen), the effect on the LI-6400 is to increase the apparent CO₂ by about 2 parts per million, at ambient CO₂, because the flow decreases through the system due to decreased viscosity of the air by 2.7%, and cause a small error (less than +0.4%) in the LI-6400 flow meter reading. In order to correct the apparent CO₂ concentration for O₂ concentration, the effective pressure of the air mixture must be calculated from the product of the partial pressure of each constituent gas and its corresponding band-broadening coefficient. We found the apparent band broadening coefficient for oxygen to be 0.9 for the LI-6400. We present the equations necessary to make corrections online or after the fact.

RESULTS AND DISCUSSION

As the O₂ concentration is lowered, the viscosity of the air decreases and the flow rate of air through the CO₂ injector system increases. Figure 2 shows the relationship between flow rate through the system as a function of oxygen concentration, normalized to the ambient (21%) case. This mixing factor is applied to the raw measured CO₂ values to compensate for these flow changes.

\[ C_{c, ao} = (1 - \chi)(C_{c, m} + \delta_{c, ao}) \]

where \( C_{c, ao} \) is flow corrected CO₂, \( C_{c, m} \) is raw measured CO₂, and \( \delta_{c, ao} \) is oxygen corrected CO₂. The error in the LI-6400 flow meter was found to be less than +8% under oxygen-free conditions. Variation in \( C_{c, m} \) with oxygen is assumed due to band broadening effects. Figure 4 illustrates the flow correction, and also a band broadening correction with a value of \( a_{oa} = 0.9 \). Figure 4 illustrates the effect of the band broadening correction with a range of values for \( a_{oa} \). The optimum value of \( a_{oa} \) was chosen by plotting the slopes of the error curves in Figure 4 as a function of \( a_{oa} \) and finding the average intercept (Figure 5). The average intercept value is 0.9 (Table 1). This band broadening formulation (Equation 4) has been implemented in the LI-6400 in OPEN version 5.2.

A post-data collection correction can be formulated based on these measurements. This correction factor has the form

\[ C_{c, ao} = (1 - \chi)(C_{c, m} + \delta_{c, ao}) \]

where \( C_{c, ao} \) is oxygen corrected CO₂, \( C_{c, m} \) is raw measured CO₂, and \( F(C_{m}) \) is given by

\[ F(x) = (1 - \alpha_x)^{\epsilon_x} \]

where \( \alpha_x = 0.0001(\chi) \), and \( \epsilon_x = 0.0000751 \). \( F(x) \) is shown in Figure 6, and was determined from the 21% oxygen measurements by differencing the flow corrected CO₂ values for \( a_{oa} = 0.9 \) and \( 0.9 \). There is an assumption of linearity with oxygen concentration.

SUMMARY

The errors in the LI-6400 caused by varying oxygen concentration are negligible (0.4% for oxygen-free air). The errors caused in the LI-6400 IRGA are more significant (+2 ppm for oxygen-free air), but are compensated adequately by a band-broadening based solution that uses a band broadening coefficient of 0.9. This solution is part of OPEN 5.2 software for the LI-6400.

REFERENCES

Burch, D.E., E.B. Singleton, and D. Williams. 1962. Absorption line broaden-


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