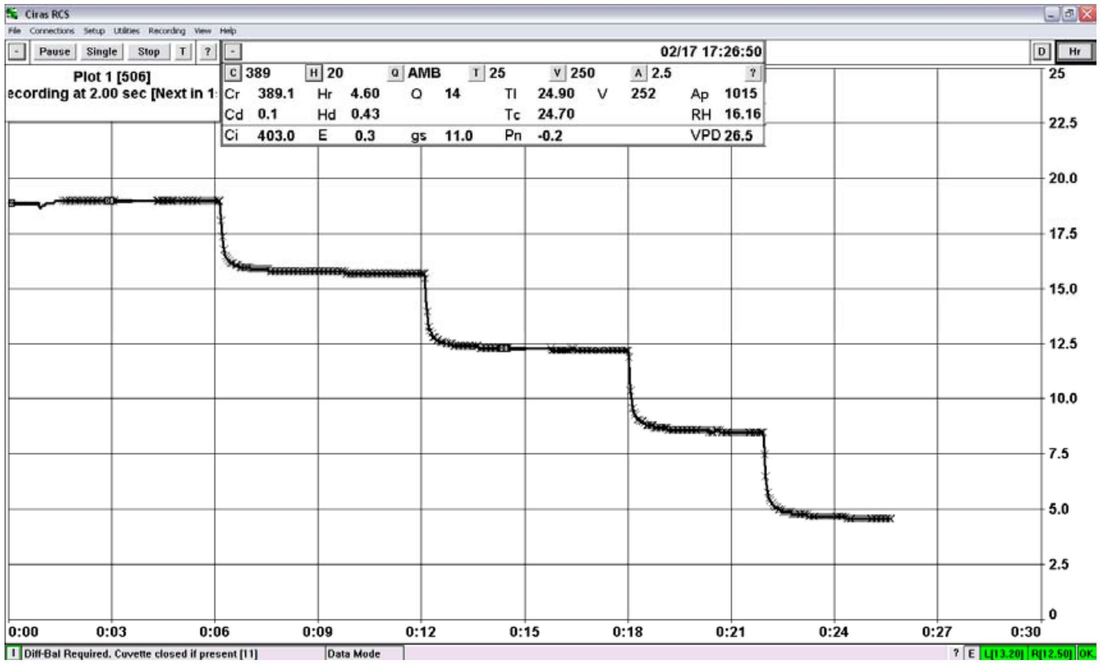
Application Note #2011-01

Stability and Accuracy of CIRAS-2 Water Vapor (Reference Humidity): Control Option 1



Summary

Rapid large-scale fluctuations of carbon dioxide and water vapor, although unnatural and artificial in the plant world, are desirable attributes for gas exchange systems from a sampling efficiency standpoint. As PP Systems' benchmark IRGA system for gas exchange and photosynthesis research, CIRAS-2 was designed for and expected to have exceptional response times to user-initiated changes in reference gas concentrations of CO_2 and water vapor. This document provides information and data specific to the most commonly used water vapor control option available with CIRAS-2, H2O control option 1 ('Supply (Ref) % of Ambient').

Supporting evidence is mainly in the form of simple timed profiles of reference water vapor, from a stable origin condition through the delta phase, to the target steady-state condition. This information, analogous to operator uncertainty about (leaf) physiological stability, can help CIRAS-2 users determine when the system is likely to be stable, and the degree of stability following experimental changes. It also indicates the target accuracy of selected changes below ambient, both in terms of measured output (partial pressure, mb) and calculated output (%RH).

CIRAS-2 has five menu options for operator control/manipulation of leaf chamber water vapor. For CIRAS-2 users, it is at times a source of confusion as to which option is best – generally speaking, the first two options (% of Ambient and Set mb) provide the most stable reference water vapor. The control itself is based solely on diversion (valve duty-cycle) of the reference gas through the air supply dessicant columns (orange color-indicating Envirogel), and not subject to feedback from the leaf in the chamber (Analysis gas control options).

Test Design

CIRAS-2 was allowed to warm up for 30 min. in the standard open-system portable photosynthesis mode, with an attached PLC6 cuvette. Within 5 min. the system was operating normally in Measure mode, having attained its stable IRGA temperature of 55 ºC and performed Autozero (Z) and Differential Balance (DB) functions. With the leaf chamber empty and closed and the cuvette temperature stabilized at 24.7 ºC, the stable reference partial pressure of water vapor was determined to be 19 mb, with a firmware-calculated RH of 60%.

It is important to note that this humidity level, sometimes referred to in CIRAS-2 operational literature as "ambient", is in fact artificially elevated above true background ambient. This is due to unintentional humidification of the reference gas stream passing through soda lime, between the air forwarding and main air supply pumps. The water vapor equilibrator, next in line along this path, removes a large portion of this water vapor, but fails to remove it entirely. Although this is documented in the CIRAS-2 Operator's Manual ver. 2.04 (2010), it remains a point of confusion for some CIRAS-2 users. For instructions on determining external ambient RH, see CIRAS-2 Operator's Manual (Determination of Ambient RH).

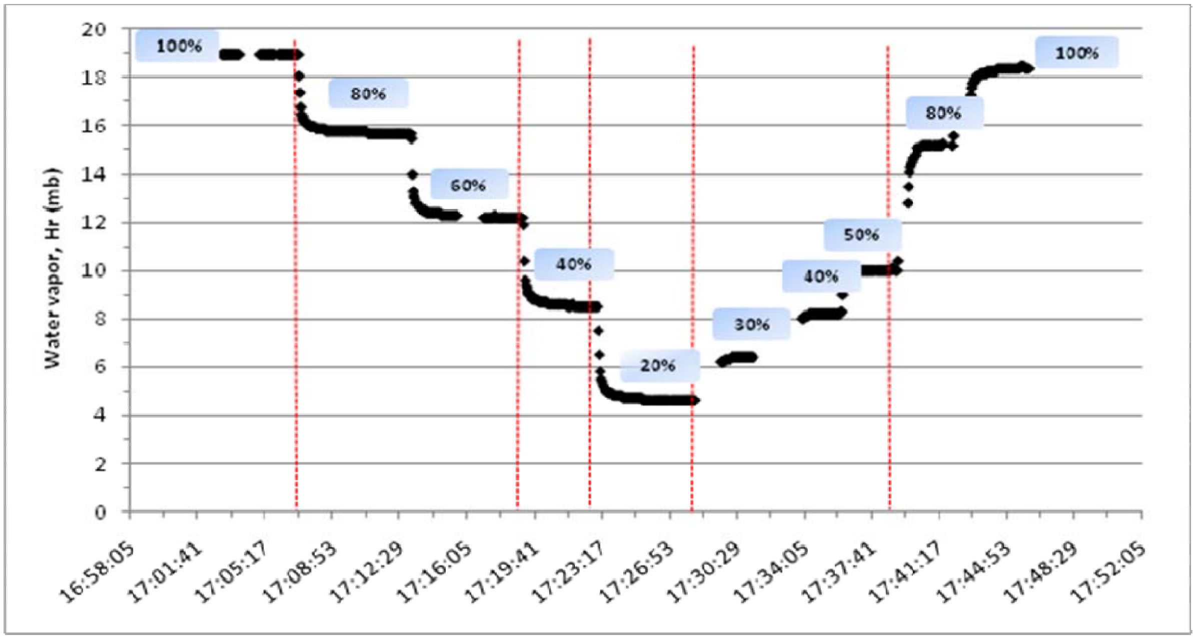


Figure 1.

As indicated, only H2O control type 1 (change on percentage basis) was tested here. Manual control was used exclusively - no instantaneous changes in water vapor were initiated by a pre-defined response curve. The left portion of Fig.1 (same as the CIRAS-2 screen shot above) shows step-wise decreases from the initial steady-state "cuvette ambient" condition through four steps, each of which was a 20% target reduction. The right portion of the graph shows increasing water vapor control back towards "cuvette ambient" in steps varying between 10, 20 and 30%. Five of the 10 response levels are presented in more detailed graph profiles below. The vertical broken lines (red) indicate the approximate point in time when each of the five highlighted level changes were initiated.

Data were recorded while in "Timed" recording mode at 2 second intervals. Typically, slight firmware/data processing delays resulted in capture of 20-23 records/minute, on average, 2.8 sec per record. For practicality, steady-state Hr at any level was defined as 60 sec of continuously stable readings.

Results and Conclusions

Using H2O control option 1 ('Supply (Ref) % of Ambient') the CIRAS-2 user can expect to wait 1:47 minutes on average for system stability with intentional changes as large as 30% from a previous steady state condition. Under the conditions tested here, two circumstances lengthen these times appreciably - Z and DB sequences (examples, Figs. 5,6) triggered by large Δmb, and water vapor control from 100% to some lower setpoint or returning to 100% of ambient. Z and DB sequences that lengthen times can be largely bypassed by use of the Stored DiffBal option, for example, while running response curves with ΔH2O exceeding 3 mb. Times to setpoint stability (Ti) marked with an asterisk indicate an intervening Z or DB.

Table 1 contains mean values for water vapor (WV) reference and differential (Hr, Hd) for each setpoint, cuvette ambient reference water vapor was 19 mb to begin the sequence. Target WV are the expected setpoint values in mb. The accuracy of % changes using option 1 is shown in the "Off Target" column – all actual values were greater than expected setpoint values. Completing the series and returning to 100% of ambient resulted in a 18.4 mb stable value – possibly due to a true decrease of 0.6 mb in room ambient humidity (external sample air), although this was unknown at the time. The percent (reduction) from ambient is approximate to the 100% level, and therefore deviation from target WV was as much as 18%, but much better at smaller percent changes from ambient.

Setpoint WV (%)	Hr (mb) ±1SE	Hd (mb) ±1SE	Target WV(mb)	Off Target (%)	ΔTime to T_i (min)
100	**19.0**±0.000	**-0.43**±0.005	---------	---------	---------
80	**15.7**±0.005	**-0.05**±0.004	15.2	+3.5	2:46
60	**12.3**±0.011	**0.22**±0.026	11.4	+7.2	1:41*
40	**8.6**±0.008	**0.37**±0.015	7.6	+11.3	1:23
20	**4.6**±0.005	**0.47**±0.010	3.8	+17.9	2:28*
30	**6.4**±0.006	**0.01**±0.012	5.7	+10.9	1:40*
40	**8.2**±0.000	**-0.13**±0.008	7.6	+7.3	1:17
50	**10.0**±0.004	**-0.24**±0.006	9.5	+5.1	0:59
80	**15.2**±0.008	**-0.82**±0.020	15.2	+0	1:23*
100	**18.4**±0.007	**-0.73**±0.013	---------	---------	2:26

Table 1.

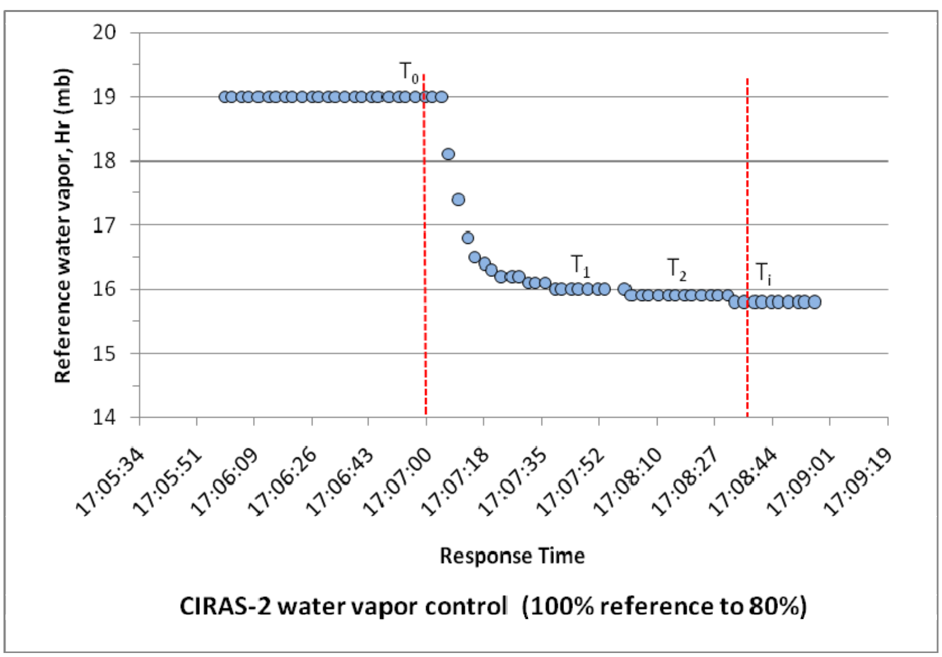


Figure 2.

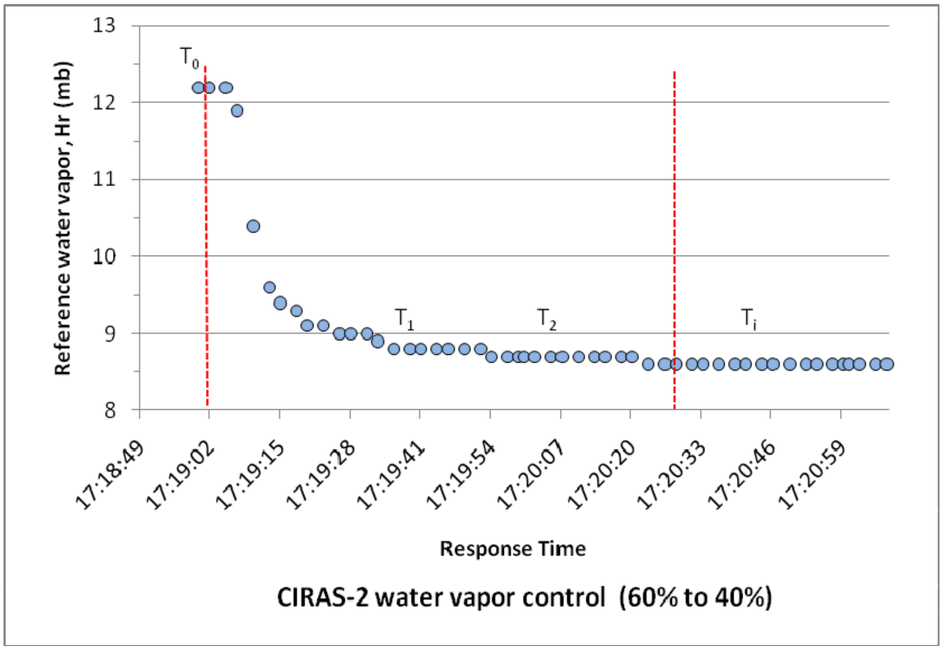


Figure 3.

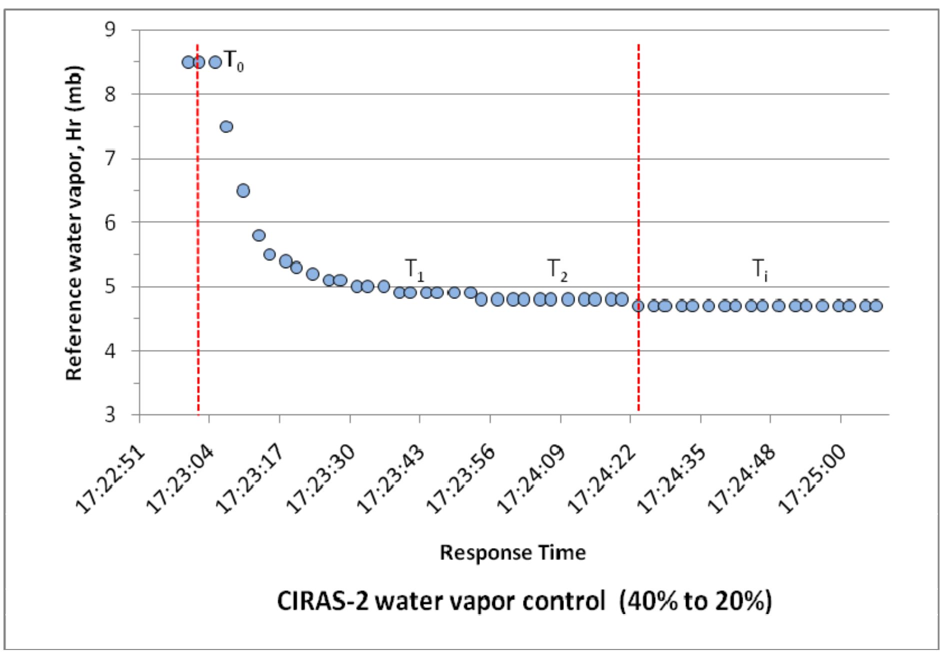


Figure 4.

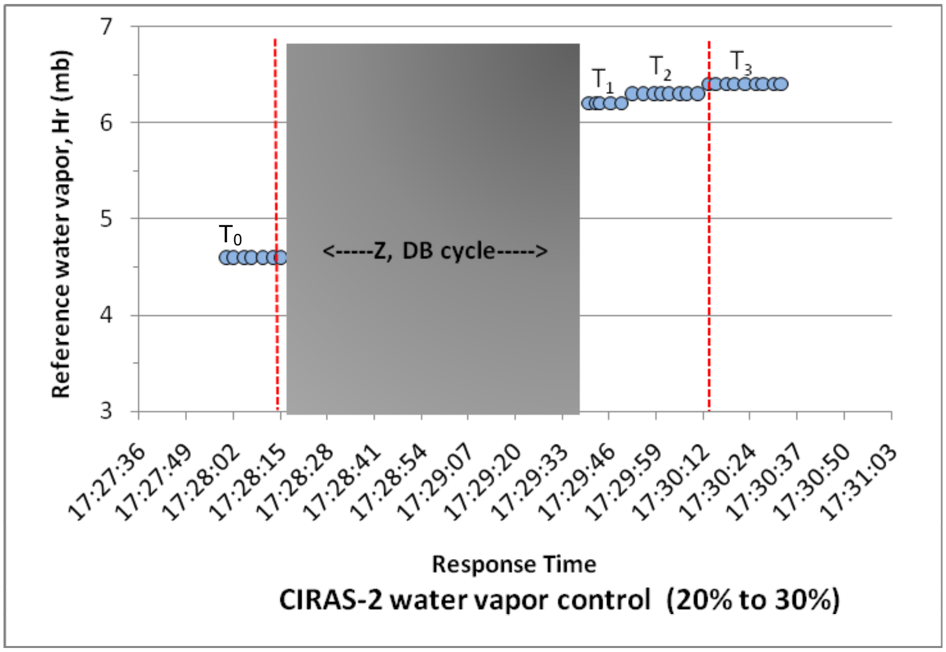


Figure 5.

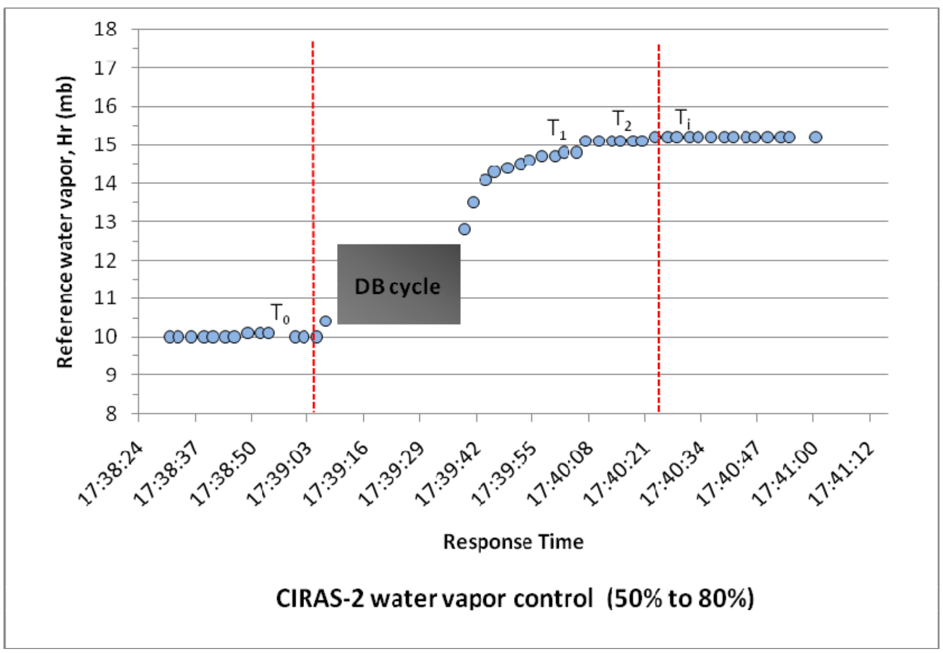


Figure 6.

Looking at these figures, the first phase in a setpoint decrease/increase always resulted in a precipitous change within 10-13 sec. In each test case there were two false or apparent stability phases (T_1, T_2) that were intermediate to the initiation of water vapor control (T_0) and final target water vapor stability phase (T_i). The mb differences between each intermediate were 0.1 mb for each test case. Depending on the desired level of stability, a CIRAS-2 user could potentially make measurements within 60 sec of the setpoint change (within the T_1-T_2 phase). The vertical broken lines (red) indicate the beginning/end of the complete T_0-T_i sequence, once stability at Ti was determined (maintained for 60 sec). CIRAS-2 users can have a high degree of confidence that both accuracy and stability are good to excellent between approximately 1:00 and 1:47 minutes (on average) of initiated setpoint changes.

PP SYSTEMS

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References:

PP Systems Inc. 2010. CIRAS-2 Portable Photosynthesis System Operator's Manual. Version 2.04.
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