

Improving the Measurement Accuracy of Water Partial Pressure Using the Major Constituent Analyzer

Ben D. Gardner, Phillip M. Erwin, Wai Tak Lee, Amber M. Tissandier and Souzan M. Thoresen
Hamilton Sundstrand Space Systems International

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ABSTRACT

The Major Constituent Analyzer (MCA) is a mass spectrometer based system that measures the major components of the International Space Station (ISS) atmosphere, including water. The measurement of water vapor has been difficult due to adsorption on various surfaces in the sample path, and has thus far been discounted in MCA atmosphere monitoring. This paper summarizes the results in identifying the primary source of the problem, the modeling being used to further elucidate the water surface adsorption/desorption process, and the proposed means available to provide a stable calibration and accurate measure of the water abundance.

INTRODUCTION

The Major Constituent Analyzer (MCA) on board the International Space Station (ISS) is a mass spectrometer-based system designed to monitor the major constituents of the ISS internal atmosphere. Of these, nitrogen, oxygen, methane, carbon dioxide, and hydrogen are being monitored as originally designed. Obtaining accurate water vapor measurements, however, has been problematic. The primary issue for water vapor measurement is the adsorption of water onto the interior surfaces of the ISS sampling lines, MCA internal sample transport lines, and the MCA analyzer itself. Whenever the partial pressure of water in the sample stream changes, a new equilibrium between the adsorbed and gas phases must be reached before a measurement will reflect the actual partial pressure. Thus, while changes in the partial pressures of the other major constituents are detected in real-time, accurate measurement of the water partial pressure is delayed.

Unfortunately, the time required to reach equilibrium is longer than current MCA operating parameters allow, so the measured values are not accurate.

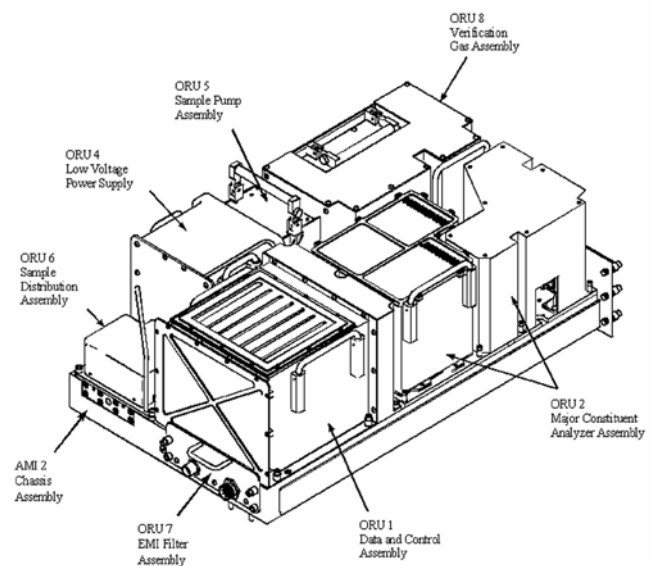


Figure 1: Major Constituent Analyzer.

This issue was apparent early on in the MCA program, when the temporal characteristics of humid air being transported from sample points in the ISS modules through various lengths of tubing was unknown. The decision was made at that time to descope water from the measurement process until a future date when the problem could be properly addressed. Recently, the MCA program has been authorized to revisit the issue as a sustaining engineering task and implement the findings as part of a series of upgrade and improvement tasks through NASA change request CR10773A.

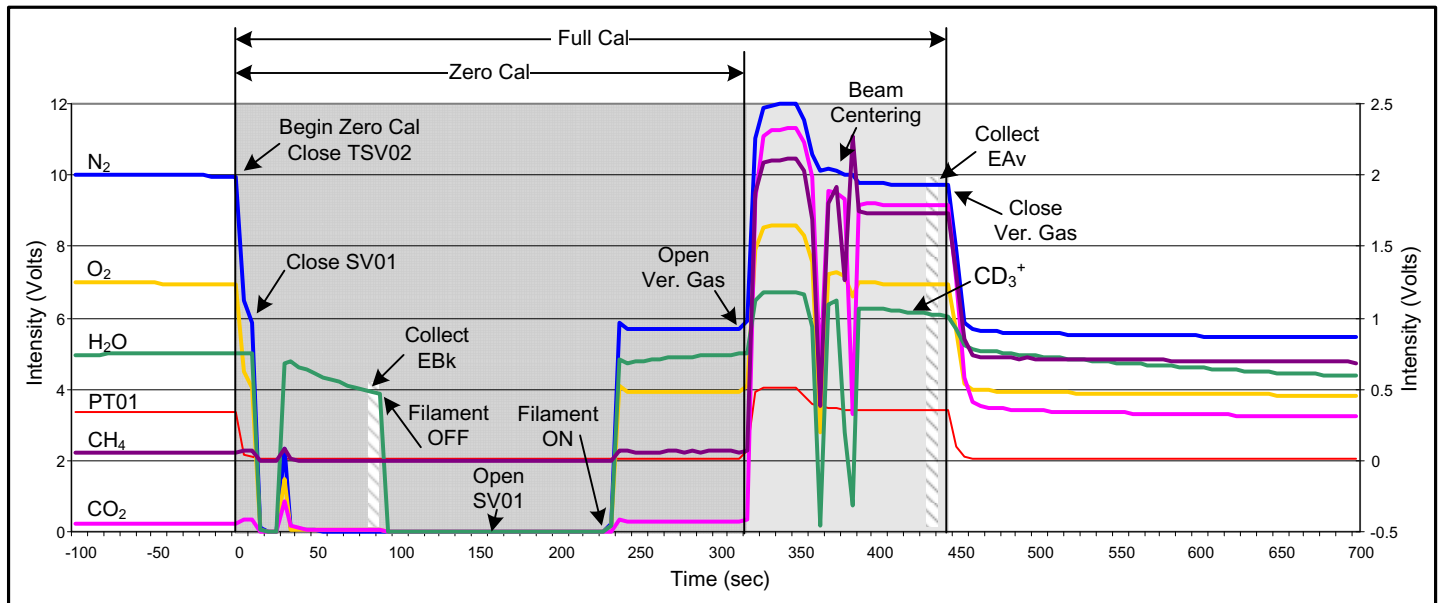


Figure 2: MCA calibration sequence. The water channel is shown in green.

This paper describes the basis for identifying the primary contributors to the water desorption time constant within the MCA, and an improved method for accurately determining the water vapor partial pressure. The method includes a revised procedure for calibrating the MCA water channel as well as a strategy, based on the modeling, for accurately estimating ISS humidity levels within the sampling times allocated for each module. The improved method is scheduled for implementation into the MCA firmware in the fall of 2009.

MCA CALIBRATION

MCA calibration is a two part process that establishes the offset and gain for each electrometer, as shown in Figure 2. A zero calibration is performed each week to verify MCA operation and establish baseline Electrometer Background values (EBk) when no gas is entering the MCA analyzer. A full calibration is performed every six weeks to establish the Electrometer Average values (EAv) when a known quantity of the verification/calibration gas mixture is introduced into the analyzer. The EBk background values and the differences between the EBk and EAv values are used to calibrate the MCA. Five of the verification gas constituents are identical to the atmospheric constituents for which the MCA was designed. However, deuterated methane (CD_4) is used to calibrate the water channel because CD_4 is not adsorbed by the system surfaces and it generates a CD_3^+ ion having the same mass to charge ratio (m/z) as ionized water.

The zero calibration is begun by closing the SV01 valve, shown in Figure 3, at the entrance of the mass analyzer. This isolates the analyzer from the rest of the MCA flow path and allows the determination of the EBk values for each channel. Obtaining accurate EBk values depends on the major constituents having reached baseline levels by the time the measurement is made.

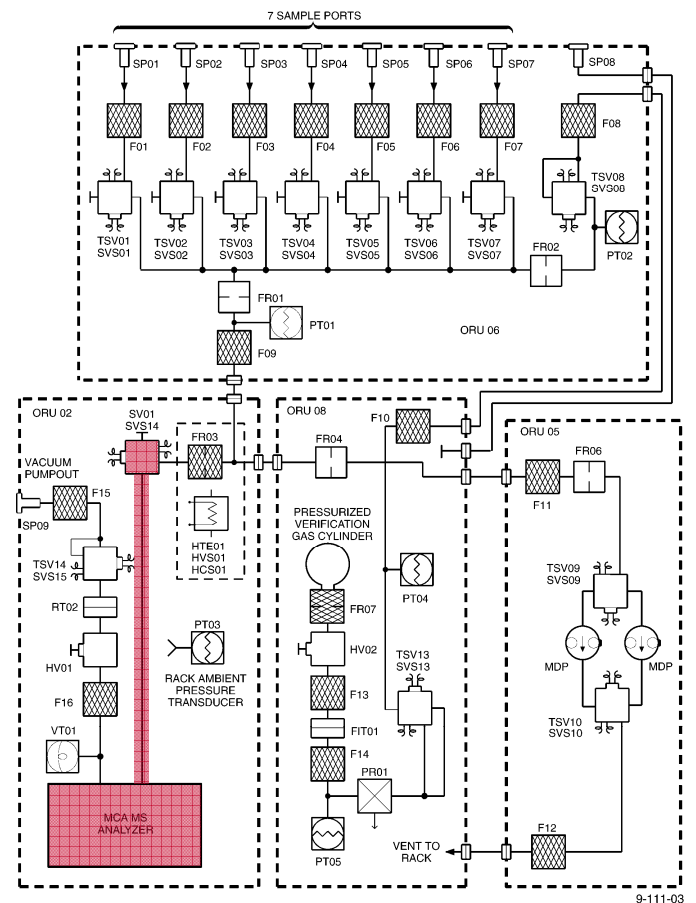


Figure 3: Schematic of the MCA showing isolated analyzer region with SV01 closed.

The time dependence for reaching the baseline is illustrated in Figure 4 using data acquired on the MCA non-flight Integration and Test Unit (ITU). Upon closing SV01, the signal levels for nitrogen, oxygen, hydrogen, carbon dioxide and methane drop to baseline levels within seconds, while the water signal does not reach a baseline level for over 100 minutes. Furthermore, while