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

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Presented at the 7th Workshop on Harsh Environment Mass Spectrometry, Santa Barbara, CA September 22, 2009
The Major Constituent Analyzer (MCA) is a magnetic-sector mass spectrometer based system for monitoring ISS air.

- Six simultaneous detection channels; for H₂, CH₄, H₂O, N₂, O₂, and CO₂ which are the major on-board air constituents of ISS.

- Is self-calibrating.

- Includes active built-in-test (BIT) capability.

- Is comprised of seven orbit-replaceable units (ORUs) for easy maintenance.
• Of the six major constituents that MCA is designed to measure, five (H₂, CH₄, N₂, O₂, and CO₂) are currently being measured as planned.

• Measurement of the sixth constituent, H₂O, was descoped during MCA development. At that time, the issue of transporting humid air through the ISS plumbing was not completely understood and the effect of H₂O surface adsorption on the sampling lines had not been characterized.

• Recently the MCA program has been authorized to revisit the issue through NASA change request CR10773A.
The Calibration Sequence

Zero Cal (Offset) → Beam Centering → Full Cal w/ VGA (Gain)

The Calibration Sequence graph shows the intensity (Volts) over time (sec) for various gases: N₂, O₂, H₂O, PT01, CH₄, and CO₂. The graph highlights different phases of the calibration sequence:

- **Zero Cal**: Begin Zero Cal Close TSV02
- **Full Cal**: Close SV01 Collect EBk
- **Beam Centering**: Open Ver. Gas Filament OFF
- **Collect EAv**: Filament ON
- **Close Ver. Gas**: CD₃⁺

The graph illustrates the intensity changes for each gas during these phases, providing a visual representation of the calibration process.
MCA Normal Operation

• The plumbing schematic for MCA is shown on the right.

• Under normal operation, the incoming air flows through an inlet valve of the MCA manifold and into the analyzer.
MCA Calibration Start
(Zero Cal)

- The plumbing schematic for MCA is shown on the right.

- Under normal operation, the incoming air flows through an inlet valve of the MCA manifold and into the analyzer.

- At the beginning of the zero and full calibration routines, the inlet valve at the analyzer entrance is closed.

- The analyzer then drops to a baseline level to establish background signal amplitudes.
The Problem with Measuring H₂O

• Measuring p(H₂O) has been problematic because, unlike the other constituent gases, H₂O adsorbs onto the interior surfaces of the transport tubing.

• Measured H₂O levels do not reflect the actual gas-phase environment until equilibrium is achieved.

• As shown in the figure, reaching equilibrium can require considerable time (>100 minutes), which is not compatible with MCA operation requirements.

• The decay characteristics are not strictly exponential.

• This phenomenon affects MCA capacity to accurately calibrate the H₂O channel and to predict ISS humidity.
Zero Calibration

- **Zero Calibration** establishes the electrometer background average (EBk).
- **Full Calibration** then uses EBk to adjust electrometer correction values (ECVs).
- Any error in EBk generates an incorrect calibration.
- As shown in the Figure, EBk is acquired before the H₂O signal is stable.
What is responsible for the slow decay?

- The primary suspect component responsible for the slow decay rate is the analyzer inlet valve, SV01.
- SV01 has a high internal surface area, low gas conductance, and is unheated.
- Laboratory experiments using the MCA Integration and Test Unit (ITU) revealed that the shape of the decay curve for H2O can be changed by heating the valve.
- However, the slow decay is not eliminated.
- Furthermore, the baseline levels do not converge even after an extended time period.
Simulink Modeling of the Decay - SV01 Valve

SV01 valve closed.

H₂O

Time (Min)

Intensity (Volts)
SV01 valve closed.

Simulink Modeling of the Decay – Analyzer

H2O background from Housing & Ion Pump (t = 1 week)

H2O background from Housing & Ion Pump (t = 10 hr)

H2O to O2

H2O to CO2

H2O to CO

H2O to Amp

N2 to Amp

CO2 to CO

CO to Amp

O2 to Amp

CO2 to Amp

CO2 to CO

CO2 to Amp

CH4 to Amp

Gain

Product

Fil

SV01 valve closed.

Time (Min)

Intensity (Volts)

0 20 40 60 80 100 120

0 20 40 60 80 100 120

H2O

PP 1

PP 1

PP 1

PP 1
• The experimental thermal and modeling data confirm that the SV01 valve is primarily responsible for the observed decay process.

• With MCA validated and on-orbit, heating the SV01 valve is not an option.

• The modeling suggests that by collecting decay curve data for a short time after one time-constant, the final baseline can be extrapolated.

• This will require a slight increase in the zero calibration time.
Full Calibration

- **Full Calibration** includes the Zero Calibration, and occurs every 6 weeks on orbit.

- **Full Calibration** uses a verification gas mixture containing CD$_4$ to determine the EAv.

- The EAv and the EBk are used to determine the electrometer correction values.

- The CD$_4$ signal rides an unknown amount of H$_2$O.
Full Calibration

- Sample pathway is closed at 200 torr and uncontrolled when the verification gas inlet is opened, raising the pressure to 400 torr.
- Verification gas is thus forced into the side ports of the manifold, diluting trapped gas-phase H₂O which can diffuse into the verification gas flow path.
- The decay observed is a function of this process as well as desorption processes including those described in the zero calibration.
- This is not a problem for normal MCA operation, where the flow throughput greatly dominates any residual diffusion.
• Switch the manifold valve TSV02 off and the Verification gas valve on simultaneously to preserve controlled flow.
• H₂O level will decay from a known initial level.
• CD₄ amplitude can be extrapolated accurately.
• **Full Calibration** includes the Zero Calibration, and occurs every 6 weeks on orbit.

• **Full Calibration** uses a verification gas mixture containing CD$_4$ to determine the EAv.

• The EAv and the EBk are used to determine the electrometer correction values.

• The CD$_4$ signal rides an unknown amount of H$_2$O.
Taking advantage of what we’ve learned

- We are altering the calibration sequence to perform beam centering first using atmospheric gas to reduce consumption of verification gas.
- The “full cal” step will be performed next to take advantage of the logic previously described.
- The “zero cal” will follow, allowing additional time to establish an accurate baseline for H₂O.
• The improved water accuracy logic is currently being programmed into the MCA firmware as part of NASA CR10773A.

• Testing is nearly complete.

• The firmware upgrade is scheduled for delivery on ULF3 in November, 2009.

• It may be possible to extend the extrapolation logic of the zero calibration to the sampling of humid air from long lengths of sample tubing. This is under review.
Acknowledgements

- MCA Development Team – Hamilton Sundstrand
- John Granahan - Boeing
- John Cover - NASA