CHARACTERIZATION AND CALIBRATION OF THE PHOENIX TECP RELATIVE HUMIDITY SENSOR IN A MARS ATMOSPHERIC SIMULATION CHAMBER.

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Abstract: The Thermal and Electrical Conductivity Probe (TECP) is an instrument in the MECA payload [1] on the 2007 Phoenix Mars Scout mission [2], mounted on the "wrist" of the Robotic Arm. In addition to making thermophysical measurements of surface and subsurface materials, the TECP also contains a capacitive relative humidity (RH) sensor. We have performed extensive testing of the TECP RH sensor at the University of Washington Mars Atmospheric Simulation Facility [3] in order to characterize and calibrate its performance under Martian environmental conditions of pressure, temperature, and humidity.

Introduction: The Phoenix Mars Lander will be launched in August 2007 for a May 2008 landing in the north polar region of Mars (latitude 65-72N) during the northern summer season (L_s 75-125). According to Viking Orbiter MAWD [4] and Mars Global Surveyor TES observations [5], this is the location and time of year when some of the highest amounts of water vapor are found in the Martian atmosphere due to heating and sublimation of the North polar ice cap – ranging from 25-75 precipitable µm [6], versus the global annual average of ~10 pr. µm. This landing site is also considered a likely place to find near-surface ground ice based on the high concentrations of hydrogen detected by the Mars Odyssey Neutron Spectrometer [7,8,9], as well as the predictions of thermal-diffusion models [10,11,12].

One of the principal themes of NASA's Mars Exploration Program is to "follow the water" - understanding the past and present distribution and behavior of water on Mars. Water-related investigations are listed as the highest priority for several of the Mars science goals and objectives in the MEPAG-2006 report [13] including: 'establish the current distribution of water in all its forms' and '...model processes that have caused water to move from one reservoir to another' (Goal I, Objective A), 'determine the processes controlling the present distribution of water, CO2, and dust by determining the daily and seasonal trends' (Goal II, Obj. A), and 'determine the present state, 3-D distribution, and cycling of water on Mars' (Goal III, Obj. A).

The TECP humidity measurements will be a key part of the multiple, complimentary datasets obtained by the TECP and other MECA instruments for addressing these questions by looking for correlations of the humidity with surface and subsurface temperatures, wind, clouds or fog seen with the LIDAR, and/or regional temperatures and weather patterns observed from orbit.

Results: The TECP RH sensor is a Panametrics MiniCap-2, a commercial capacitive polymer-based sensor whose performance at temperatures and frostpoints below –40 C was not well known. There was also concern that its response time would be too slow to track diurnal changes. It is mounted on the TECP electronics board, directly beneath a hole in the TECP housing which is covered by a permeable Teflon membrane (Fig. 1) to allow air in while keeping dust out. The capacitance is proportional to the relative humidity of the air *in contact with* the sensor, which may be significantly warmer than the outside ambient air, but should be very close to the temperature of the

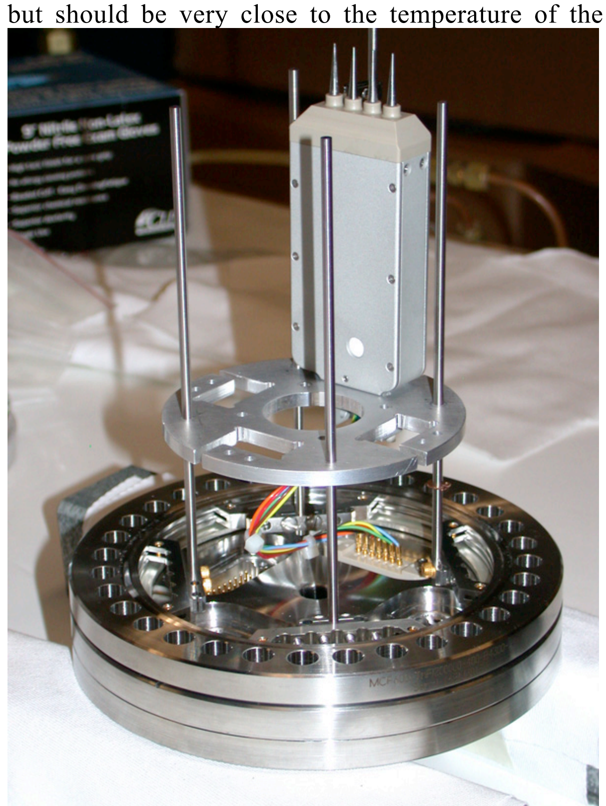
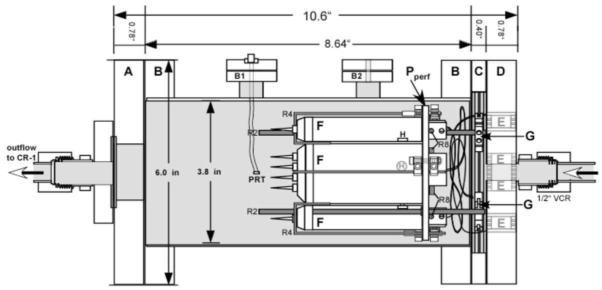


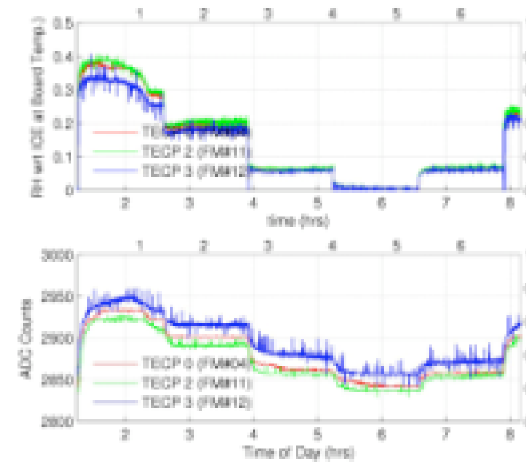
Figure 1 - TECP mounted on base flange of test chamber

electronics board (T_b) which is monitored with a calibrated thermistor. From RH and T_b we can calculate the absolute humidity, and thereby determine the RH of the ambient atmosphere as accurately as its temperature (T_a) can be measured.

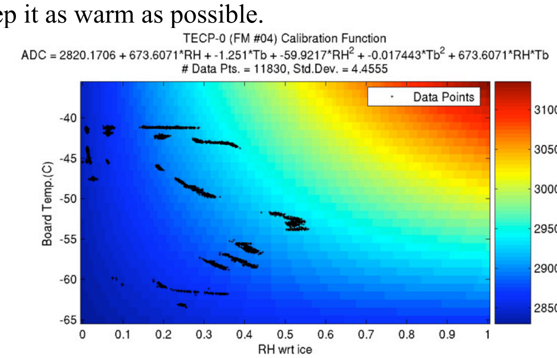


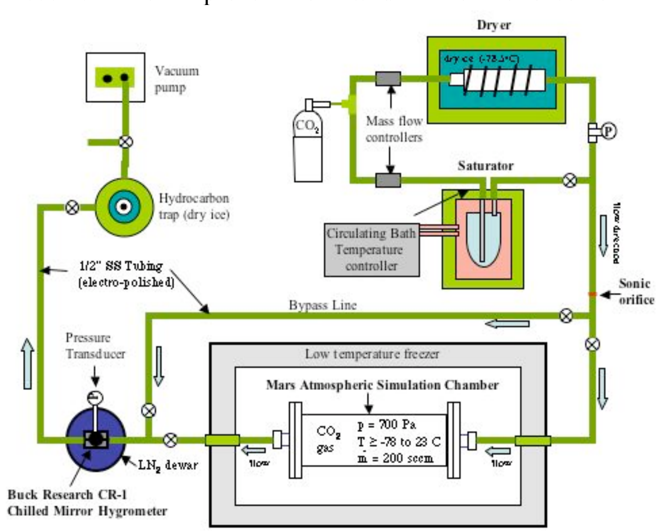
For testing the TECP RH sensor in the UW Mars Atmospheric Simulation Facility (MASF), we built a custom test chamber - designed to hold four TECP's to perform simultaneous calibration of the 4 Flight Units – using stainless steel and ceramic high-vacuum fittings to minimize adsorption and outgassing of water vapor (Fig. 2). The MASF is a flow-through system (Fig. 3), so the unavoidable hygroscopic materials such as the insulated lead wires were placed upstream of the TECP's to minimize any humidity changes between the TECP's and the reference hygrometer. The MASF also has a bypass line to monitor the humidity of the air before it enters the test chamber. The MASF reference hygrometer is a Buck CR-1 chilled-mirror hygrometer which measures the absolute humidity, or frost-point temperature (T_f) as low as –95C, with a NIST-traceable calibration for $T_f \geq$ –75C.

During calibration of the four TECP Flight Units, we collected more than 50,000 measurements, at 5 to 30 second intervals, covering a wide range of T_f (-80C to -10C) and T_b (-65C to +30C). Most of the data were collected with the chamber containing CO_2 gas at a pressure of ~5 Torr (7mb), flowing through at ~200 sccm. An example of the raw data from one set of measurements is shown in Fig. 4, which also illustrates the unexpectedly fast response time of the sensor to humidity changes (< 10 min).



The best-fit response function for the TECP FM#04 (Fig. 5) is a 6 parameter quadratic function of relative humidity and temperature, and has a standard deviation of 4.5 DN. At -60C the maximum value of the response function is only 2900, so this standard deviation represents a 5% error. However at -40C the increased range of response reduces the standard deviation to about 2%. So it will be important to consider the operating temperature of the sensor on Mars, and ways to keep it as warm as possible.





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