Experimental Heat Transfer Supporting Simulated Water Well Performance on Mars.

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Introduction: Current theory holds that Mars once had abundant water flowing on its surface, but now there is a general perception that this surface is completely dry [1]. Several lines of research have shown that there are sources of potentially large quantities of water ice at many locations, including regions considered as candidates for future human missions [2]. Recent discovery of exposed water ice scarps in Martian mid-latitudes [3] has bolstered the evidence for massive amounts of almost pure water ice in some of these regions.

These favorable indications of massive quantities of water have initiated studies of potential changes to human Mars missions if a means can be devised to make this water available to these crews [4]. One such approach relies on mechanical drills to access the water ice through overlying debris and then using a technique known as a Rodriguez Well to melt the ice, store the resulting water in a subsurface ice cavity until needed, and then pump the water to the surface for use [5]. The Rodriguez Well technique has been used in terrestrial polar regions since the early 1960's and has been supplying fresh water to the Amundsen-Scott South Pole Station since 1995.

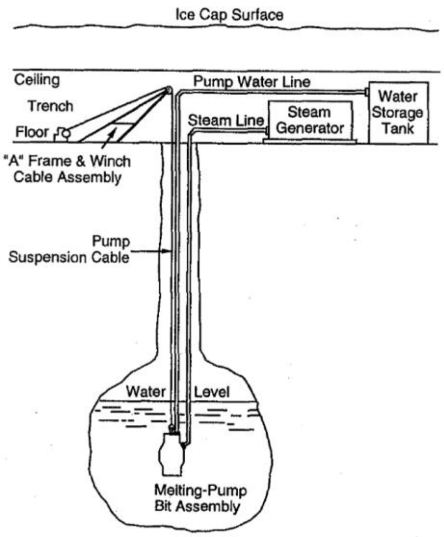

Figure 1. 1960's era Rodriguez Well [5].

Previous planning work in this area utilized a computer simulation to predict the performance of the Rodriguez Well [5]. While the basic approach used in this model is appropriate for a similar well on Mars, several parameters must be changed to correctly model the Martian environment. Parameters used in this model that are related to heat transfer between water and the atmosphere as well as between ice and the atmosphere are empirically derived. Consequently, experiments simulating a pool of water in the Martian environment are required to determine appropriate heat transfer values if this simulation is to be used in support of future Mars missions.

Simulated Mars Environment: An experiment was set up at the NASA Johnson Space Center, with the assistance of the U.S. Army's Cold Regions Research and Engineering Laboratory, to measure these heat transfer coefficients under Mars surface environmental conditions. These tests were carried out in a small bell jar, with a chamber measuring roughly 2 feet (61 cm) in diameter and 2 feet (61 cm) tall. An internal cooling shroud connected to a Julabo™ chiller allowed gas temperatures as low as -40 C.

Figure 2: NASA JSC Two-Foot Bell Jar [NASA]

The experiment used a pool of water in an insulated dewar ensuring that heat loss would only be from the top of the water pool. A resistance heater was held in the water pool and was connected to a resistance temperature detector (RTD), also in the water pool, in a feedback loop to maintain a specified water temperature: either 1° C or 2° C. The power used by the heater was a measure of the heat transferred from the water to the gas. A load cell under the dewar measured the mass loss of water due to evaporation. The interior of the chamber was instrumented with RTDs and thermocouples at various locations, heat flux sensors at the chamber wall, a pressure transducer for gas pressure, and a relative humidity sensor. A camera and LED light source were used to monitor for ice formation on or in the dewar.

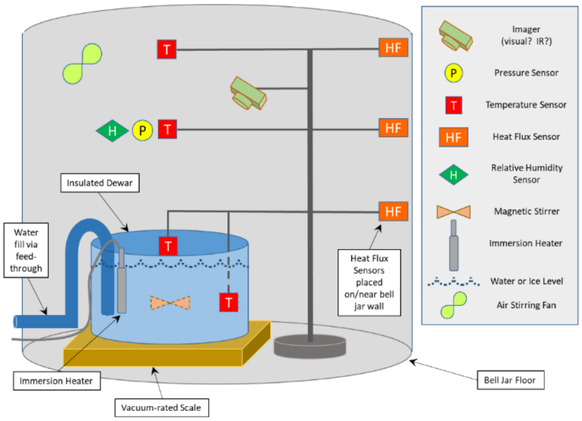

Figure 3. Experiment Setup

Experiment Test Points: Natural convection, driven by evaporation and heat flow from the pool, governs the flow regime inside a Rodriguez Well. We operated our equipment at several test points to gather data from which heat transfer coefficients and water evaporation rates could be derived. For all tests, the chamber was filled with essentially pure CO_2. Two insulated hemispherical dewars, one 11.4 cm (4.5 in) in diameter and the other 15.2 cm (6.0 in) in diameter, were used to hold the water pool, allowing tests at two different water-pool surface areas. Two gas temperature points (-20° C and -40° C) and several gas pressures, ranging from 1000 mbar (750 torr) to 8 mbar (6 torr) were used to gather these data. Test conditions were chosen to learn whether the experimental work of Bower and Saylor [6] that related natural-convection flow properties to evaporation rates in terrestrial conditions, via dimensionless Rayleigh and Sherwood numbers, could be extended to Mars surface conditions. In all, 12 combinations of pressure, temperature, and water pool diameter were used in this experiment.

Initial results: Tests at all 12 test points have been completed and data are being evaluated. Quantitative results for convective mass and heat transfer and the degree of correlation with Bower and Saylor will be an outcome of these evaluations. However, one clear outcome from the tests is that a water pool representative of a Rodriguez Well can be created and maintained at a 1° C to 2° C under Mars surface pressure and temperature conditions.

Conclusion: Favorable indications of massive quantities of water on Mars have initiated studies of potential changes to human Mars missions. Using a technique known as a Rodriguez Well to melt the ice, store the resulting water in a subsurface ice cavity until needed, and then pump water to the surface for use is one potential means to effect these changes. A computer simulation of the Rodriguez Well in a terrestrial environment is one of the engineering tools being used to characterize the performance of this type of well on Mars. An experiment at the NASA Johnson Space Center is gathering data for convective heat transfer and evaporation rates at Mars surface conditions so that this computer simulation can be properly modified to predict performance on Mars. While quantitative results await processing, tests have indicated that a pool of water can be maintained at 1°C to 2° C while at Mars surface temperatures and pressures.

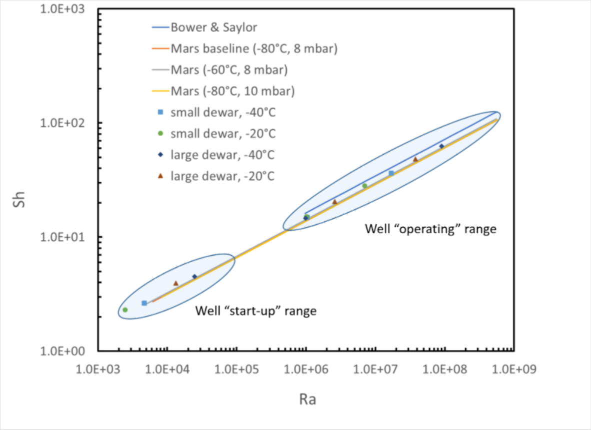

Figure 4. Anticipated Results Plotted With Bower and Saylor Results.

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