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A Titan simulation chamber

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Abstract

As a result of the measurements acquired by the Cassini-Huygens mission, Titan conditions can now be simulated in the laboratory and samples can subsequently be subjected to those conditions. The properties of a new facility to simulate Titan's environment are presented, including methodology, design, implementation, and pilot results.

1. Introduction

Saturn's largest satellite Titan, with its thick atmosphere, clouds, polar lakes, and fluvial morphologies, indicates a complex hydrological cycle. However, unlike Earth's hydrological cycle, which consists of one constituent, Titan's cycle may involve many constituents such as methane, ethane, and propane [2,4,5]. To that end, we've adapted our long-standing Mars simulation facility to have the additional capability of simulating the surface and atmosphere of Titan. The primary goal of this research is to experimentally determine the short and long term stability of light organic volatiles at the surface and subsurface of Titan [1,3]. Experiments on the evaporation rates of methane, ethane, etc., and mixtures thereof will characterize diffusion through the N_2 atmosphere near the surface as well as through the uppermost few centimeters of simulated regoliths.

2. Simulation Chamber

The concept of operation is straight-forward: determine methane (or other sample) evaporation rates by continually weighing the sample as it evaporates, while monitoring the evaporated gas concentrations in several locations within the chamber via a gas chromatograph (GC) fitted with a flame ionization detector. Our chamber, as previously used by Sears et al. [6], is a stainless steel upright cylinder with an internal diameter of 61 cm and height of 208 cm. Access is through a hoist-operated lid. A 10 cm outlet at the bottom of the chamber leads to a Kinney KDH (83 CFM) vacuum pump. A chiller operates by flowing an ethylene glycol/water mixture via a GE 1.5 HP pump through 52 meters of 1.27 cm copper tubing surrounding the chamber. The chamber is wrapped in ~20 cm of fiberglass insulation and is encased in an aluminum cabinet 1.2 m by 1.2 m by 2.4 m.

2.1 Titan Module (TM)

The apparatus consists of a removable module that is lowered within the Andromeda chamber via a hoist, along with ancillary tubing and electrical connections. A simulated Titan atmosphere is achieved by evacuating the chamber, then filling with nitrogen to 1.5 bar. Methane or other sample liquids are then introduced as described below. The lower portion of the module is a cylindrical steel housing with a diameter of 53 cm and height of 53 cm. Contained within this housing is a temperature control box (TCB) with a diameter of 36 cm and height of 38 cm. It rests on a small platform within the module and is surrounded by fiberglass insulation. The TCB is surrounded by ~15 m of 0.95 cm diameter 318L stainless steel tubing through which liquid nitrogen (LN_2) flows. Residing within the TCB is a stainless steel Friedrich style condenser 8.9 cm in diameter and 28 cm in height. At the bottom of the condenser is a Valcor SV97 solenoid valve which, when opened, pours the condensed sample liquid into a pan where it is continuously weighed while the liquid evaporates, thus determining the evaporation rate under the simulated conditions. The pan containing the liquid sample is located within the TCB, while the balance sits on a platform above the module's enclosure to prevent exposure to cryogenic temperatures. Braided line connects the pan to the balance above. The line passes through ceramic tubing to minimize heat transfer between the TCB and surroundings. Fitted around the condenser is a canister where LN_2 can be introduced via a bayonet. By regulating the amounts of LN_2 in the condenser coils, canister, and the amount of sample gas in the condenser, variable amounts of liquid can be condensed. This simple yet effective configuration yields the liquid sample desired, which is subsequently poured into the sample pan via the solenoid valve (Figure 1).

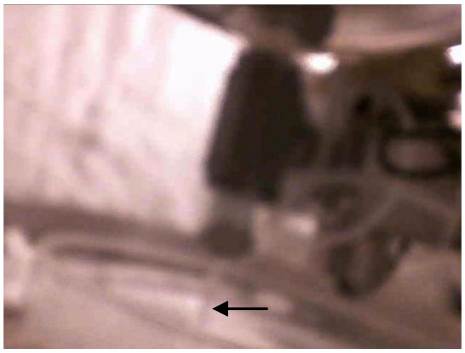

Figure 1: Liquid methane (arrow) pouring into the sample pan via a solenoid valve. The pan is suspended from a scale and continuously weighed.

2.2 Data acquisition and control

To maintain the module concept of the Titan experiments, our data acquisition and control system (DACS) is a combination of the original Andromeda system coupled with the additional (and removable) Titan capabilities. The computer interface for the scale and pressure sensors, along with the thermocouples attached to the Andromeda chamber, are part of the original system, and data is acquired via LabView software. The Titan Module utilizes an Omega thermocouple data acquisition module and a Watlow EZ-Zone PM temperature controller operated via Specview software. The solenoid valve, and all LN_2 and gas inputs are operated manually.

3. Discussion

Titan relevant temperatures are achieved by continually flowing LN_2 through the coils of the TCB and by the addition of LN_2 into the canister. Pilot results are shown for temperature (Figure 2), and mass of a methane sample during the same run (Figure 3).

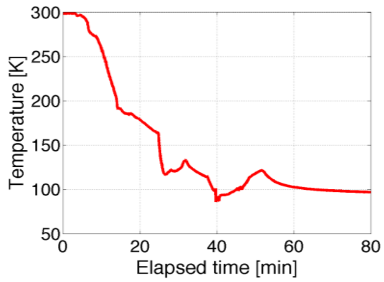

Figure 2: Chamber atmospheric temperature over the course of a run.

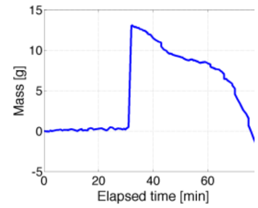

Figure 3: Mass of CH_4 over time.

Acknowledgements

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