Raising HEL: The Newest Lab for Hot Experiments

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Introduction: As the Venus community prepares for the launch of the three recently selected missions to Venus, the importance of *in situ* experiments replicating the hellish environment of Venus is becoming more evident. In addition to providing scientific and component testing in preparation of these missions, the resulting observations and measurements can only be understood with supporting theoretical and laboratory research.

Venus hosts an oppressive environment with high surface temperatures and pressures (~740K and ~95 bar, respectively), and a chemical regime primarily composed of CO_2 (~96.5%) and N_2 (~3.5%) with trace amounts of other reactive gases including sulfur species (SO_2, H_2SO_4, etc.). This environment creates many technical challenges, but it is crucial to design systems that can simulate the temperature, pressure, and chemical conditions to (1) develop and test exploration technologies, and (2) for the scientific study of the current environment and natural processes that brought Venus to become the enigmatic planet we love.

Specifications: To meet this need, the Hot Environments Laboratory (HEL) at NASA Goddard Space Flight Center has been developed to serve the community by providing *in situ* laboratory data at temperature regimes frequently difficult to simulate and maintain. In addition to our original powerhouse VICI (Venus *In Situ* Chamber Investigations), the laboratory has added a smaller Venus simulation chamber. Both chambers can simulate a range of Venus relevant temperatures and pressures up to 740K and 95bar, a wide range of gas species, and offers viewing ports and/or throughputs for data and power.

There are two thermogravimetric (TG) systems covering a temperature range from ambient to 2500K, and operates under a low-flow, inert gas or vacuum conditions. One of these TG systems is fit with differential thermal analysis (DTA) and differential scanning calorimetry (DSC) capabilities and can also provide evolved gas analysis (EGA) of materials via a heated connection pathway to a FTIR (Fourier Transform Infrared) spectrometer and/or a mass spectrometer.

The two available FTIR spectrometers can take spectra from VIS-MidIR and include two variable temperature (ambient - 1200K) and pressure (10^{-10} – 100 bar) FTIR cells that can be used for experiments with gases, liquids, and solids. Also, a long-path (30 m) gas cell has recently been acquired to begin experiments on gas-gas interactions and take measurements of vapor species to the ppb levels

With the listed equipment the Hot Environments Lab can take *in situ* measurements over a wide range of extreme conditions. The flexibility of this equipment allows for a wide range of tests and can be used to simulate various hot environments such as early Earth, planetary interiors, and to date, has been used in studies focused on Venus and exoplanets. Going forward, this lab will be supporting the DAVINCI (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging) mission by assisting with the plan, development, and testing of hardware for Venus exploration. Additionally, it will provide a testbed facility for scientific investigations of the Venus environment to prepare for, test, and assist in interpreting data acquired by DAVINCI.

Interpretations of mission and ground-based observations require an accurate understanding of the chemical and physical properties of planetary materials, regardless of if the target in our local neighborhood or is an exoplanet in a faraway system. This understanding can only occur by utilizing results from modeling and laboratory experiments.

The Hot Environments Lab will serve a role in supporting planetary research by serving to validate and test planetary observations and models, and to ensure maximum science return of observations during this new Decade of Venus.

How to gain access: The equipment listed here is available for community use and there are frequent positions available for interns, grad students, and postdocs.

To obtain time for any of the listed equipment, please contact Erika Kohler at Goddard Space Flight Center (email: erika.kohler@nasa.gov).