RESOLVE (Regolith & Environmental Science & Oxygen & Lunar Volatile Extraction) Project

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Abstract

The RESOLVE Project is a lunar prospecting mission whose primary goal is to characterize water and other volatiles in lunar regolith. The Lunar Advanced Volatiles Analysis (LAVA) subsystem is comprised of a fluid subsystem that transports flow to the gas chromatograph – mass spectrometer (GC-MS) instruments that characterize volatiles and the Water Droplet Demonstration (WDD) that will capture and display water condensation in the gas stream. The LAVA Engineering Test Unit (ETU) is undergoing risk reduction testing this summer and fall within a vacuum chamber to understand and characterize component and integrated system performance. Testing of line heaters, printed circuit heaters, pressure transducers, temperature sensors, regulators, and valves in atmospheric and vacuum environments was done. Test procedures were developed to guide experimental tests and test reports to analyze and draw conclusions from the data. In addition, knowledge and experience was gained with preparing a vacuum chamber with fluid and electrical connections. Further testing will include integrated testing of the fluid subsystem with the gas supply system, near-infrared spectrometer for the Surge Tank (NIRST), WDD, Sample Delivery System, and GC-MS in the vacuum chamber. Since LAVA is a scientific subsystem, the near-infrared spectrometer and GC-MS instruments will be tested during the ETU testing phase.

Background Information

RESOLVE is a lunar prospecting expedition whose primary goal is to characterize water and other gas volatiles in lunar regolith. RESOLVE consists of LAVA, OVEN, Avionics, Software, Thermal and Structures Subsystems. The Resource Prospector will be sent to prove that water can be accessible on the moon and other planetary bodies. The rover will look for essential gases inside of craters, where the remains of comets (made of ashes, dust and iced water) will be located. The rover will then drill into the lunar soil to extract soil, which will then be heated inside the OVEN subsystem. This will release gas particles into a streamline to lead to the ST/NIRST, which will then vent molecules to the SDS/GC-MS and WDD.

Figure 1. RESOLVE Logo. *RESOLVE Payload patch.*

Figure 2. RESOLVE Payload and Resource Prospector Rover Field Test Unit. *The LAVA subsystem is depicted in the black box on the rover. Photo credit: NASA/Dmitri Gerondidakis*

The Resource Prospector will complete its mission in seven days. RESOLVE is a combined effort between the NASA's John F. Kennedy Space Center, Jet Propulsion Laboratory, Ames Research Center, Johnson Space Center, Marshall Space Flight Center, and Glenn Research Center with potential international. RESOLVE started out as an exploratory project that took the proven concept using a hydrogen reduction reaction and adding hydrogen to react with oxides in soil and form water. It was then expanded to prove that this concept would be able to be done on another terrestrial body, in order to make essential resources on the moon or Mars. RESOLVE is a Class D mission and is expected to fly in 2020.

Experiments and Design

The FSS is currently in the engineering testing unit phase, which is posed to help further improve design reliability for the flight mission. Testing and experiments will include pressure transducers repeatability testing, RTD efficiency and reliability testing, heat wrap efficiency testing and manifolds heating effectiveness testing. All experimental design was done by Dr. Mary Coan, Dr. Janine Captain, Lucas Lance, Kate Cryderman, and Beau Peacock.

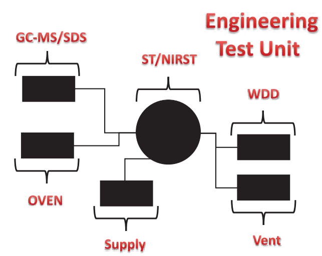

Figure 3. Engineering Test Unit Subsystem Layout. *Fluid Subsystem diagram showing all components of the RESOLVE payload.*

Pressure Transducer Qualification Testing

- The PT testing comprised of taking the experimental setup and utilizing pressure changes in conjunction with temperature changes. The PT's are used as pressure monitors inside of the manifold, while the rover is running. Temperature will be kept constant, while the pressure of the system is changed.

Heat Wrap Analysis Testing

- The goal during the heat wrap analysis test is to determine the most efficient method to heat trace 1/8th inch stainless steel tubing that minimizes heat loss and uneven heat distribution. Thermal profile will help to determine the cooler spots along the tube, where the RTD's will be placed.

Mini-Manifold Thermal Profile Testing

- The goal of the Mini-Manifold Test is to determine if the 6'' piece of tubing is able to reach a certain temperature with either the line and/or manifold heaters turned on. The experiment also shows any temperature inconsistencies across the tube.

Results and Findings

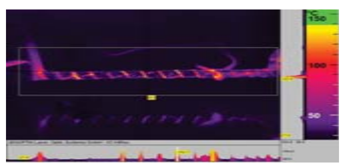

Figure 4. Three Wraps/Inch Thermal Profile. *Picture taken after 30 seconds after reaching 150 °C.*

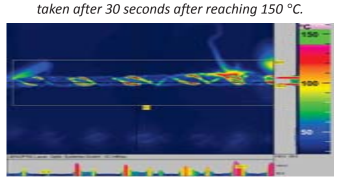

Figure 5. Two Wraps/Inch Thermal Profile. *Picture taken after 30 seconds after reaching 150 °C.*

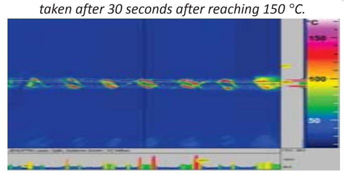

Figure 6. One Wraps/Inch Thermal Profile. *Picture taken after 30 seconds after reaching 150 °C.*

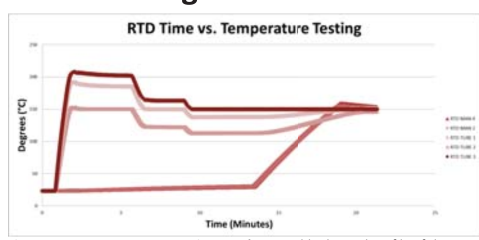

Figure 7. RTD Temperature Testing Results. *Possible thermal profile of the mini-manifold system from temperature observations.*

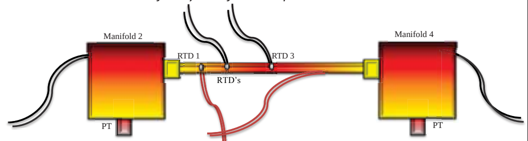

Figure 8. Pressure Transducer Testing Output Diagram. *Possible thermal profile of the mini-manifold system from temperature observations at 10 minutes.*

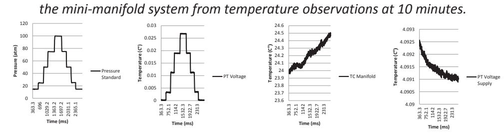

Figure 9. Pressure Transducer Testing Outputs. *Testing outputs includes pressure voltage applied, temperature, and voltage supply, from left to right, respectively.*

Results and Findings (Cont.)

Pressure Transducer Qualification Testing Results

- Each of the PT's will be installed onto the Integrated Manifold as part of the Fluid Subsystem. The ETU integrated manifold will help control the manifold, heaters, temperature and pressure sensors, orifices, values, tubing and fluid components. The PT test will allow for a wide range of temperatures and pressures that will emulate the operational and non-operational modes throughout the mission lifetime.

Heat Wrap Analysis Results

- Testing of the heat wrap variables has shown that three wraps per inch results in the least amount of heat loss, reached desired temperature fastest, most even heat distribution and is easiest to assemble. More coverage also limits the amount of tubing exposed, minimizing the risk of potential damage.

Mini-Manifold Thermal Profile Testing Results

- With all heaters (line and both manifold 2 & 4 heaters) at the same temperature, RTD 1 cannot reach the same temperature, but remains slightly lower, at steady state. In order to reach 150°C, RTD 1 must be either heated by the power going through the heaters, insulated, or the metal must be changed in order for heat to transfer more efficiently.
- RTD 1 is located right near Manifold 2, but because stainless steel has such a low thermal coefficient compared to Aluminum 6061, the heat does not transfer over quick enough to heat RTD 1 to operating temperature. The line heater does disperse energy evenly, but the aluminum manifold draws heat away from the stainless steel tubing.
- The lowest temperature areas are located at the ends of the tube, due to stainless steel thermal coefficient and the stainless steel bolts. Better line heater is advised and stainless steel tubing is advised to be replaced with copper or another more conductive metal.

Conclusion

RESOLVE may lead an essential exploratory expedition in the future and humankind missions of extraterrestrial bodies that utilizes resources from surrounding planetary bodies. With a growing interest from NASA, RESOLVE may be one of the possible solution to assist in humankind's exploration across the galaxy.

References

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