Shuttle to carry 'Constrained Vapor Bubble' experiment to International Space Station

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The Constrained Vapor Bubble project, which will launch on Space Shuttle Discovery and be installed on the International Space Station, could yield important fundamental insights into the nature of evaporation, condensation, and boiling, as well as generate engineering data that could lead to the development of new cooling systems for spacecraft and electronics devices. Credit: NASA

An experimental heat transfer system designed by researchers at Rensselaer Polytechnic Institute is scheduled to depart Earth aboard Space Shuttle Discovery. Astronauts will install the system into a laboratory of the International Space Station, where it will remain for up to three years.

The project, called the Constrained Vapor Bubble (CVB), could yield important fundamental insights into the nature of heat and mass transfer operations that involve a phase change - such as evaporation, condensation, and boiling - as well as engineering data that could lead to the development of new cooling systems for spacecraft and electronics devices.

The Space Shuttle Discovery is expected to lift off in the early hours of Wednesday, August 26. Rensselaer professors Peter Wayner and Joel Plawsky, who are leading the scientific investigation in collaboration with the National Aeronautics and Space Administration (NASA) Glenn Research Center, will be in Florida at the John F. Kennedy Space Center to watch the launch.

"After years of hard work to advance this project to its current state, I am very excited to see our Constrained Vapor Bubble make its way into space and onto the International Space Station," said Wayner, a 1956 Rensselaer graduate and professor emeritus in Rensselaer's Department of Chemical and Biological Engineering.

"The CVB experiment will provide a wealth of scientific and engineering data critical to the development of advanced materials, advanced devices, and reliable temperature and environmental control systems for extraterrestrial manned stations or interplanetary exploration missions," said Plawsky, also a professor in the Department of Chemical and Biological Engineering.

The CVB is concerned with the three-phase contact line where vapor, liquid, and solid meet, generally during the process of evaporation or condensation. This phenomenon is responsible for a number of everyday occurrences, such as a coffee ring stain on the inside of a mug, or the tears that form on the inner surface of a glass of wine. Even though the material interactions at the three-phase contact line occur in a region where film thicknesses are tens of nanometers, they are still connected to a bulk fluid region and are affected by gravity.

To truly understand what occurs at the contact line, Plawsky said, gravity must be removed from the equation. Operating the CVB in the International Space Station, therefore, will allow them to test and observe how the three-phase contact line behaves in the near-weightlessness of microgravity.

The CVB is a small glass vial with squared corners, about 30 millimeters long, filled with vapor and liquid. This tiny, wickless heat pipe is then exposed to a heat source on one end and a cold sink on the other. A camera attached to the NASA Light Microscropy Module (LMM) will capture the action as the liquid evaporates at the hot end, the vapor travels to the opposite end of the pipe where it is cooled, and the newly condensed liquid flows back toward the heat source, via capillary forces, to repeat the cycle.

The phase changes result in interesting films forming all along the inside of the glass heat pipe. This will be the first time that scientists will have the opportunity to observe evaporating and condensing menisci - the curved liquid regions at the corners of the CVB - in a microgravity environment.

"Wickless heat pipes are self-contained, as they require no moving parts or machinery to pump fluids and heat," Plawsky said. "These devices are ultra-reliable, can operate indefinitely as long as a heat source and cold sink are available, and so are perfect for space exploration purposes."

Images of the experiment, representing contour maps of the liquid film thickness, will be sent to Wayner and Plawsky, who will analyze the images to determine the distribution of liquid along the axis of the heat pipe. They will use these measurements, along with temperature measurements, to calculate the rate of heat transfer and fluid flow throughout the device. Plawsky said he expects the heat pipe to perform about 10 times better in space than it does on Earth.

From a fundamental science perspective, the experiment should allow researchers to develop a better understanding of how to control phase change processes. This potential ten-fold improvement that comes from moving to a microgravity environment could lead to the development of new cooling and heat-transfer systems for spacecraft or satellites. The new pool of knowledge about heat transfer could also lead to improvement in terrestrial heat transfer devices, such as heat pipes for the cooling of computer chips, LEDs, and photovoltaic devices, implantable heat pipes used to help mitigate the effects of epilepsy, and larger-scale machines that boil liquids. Molecular self-assembly processes that rely on exploiting evaporation would also benefit from the data.

The first part of the experiment is set to be installed in the next few weeks in the International Space Station's Destiny Module. To calibrate the machine, the very first tests will take place in late 2009 or early 2010 and will use a heat pipe that contains no liquid. Following the calibration, a second heat pipe containing the liquid pentane will be installed and tested. Another space flight targeted for July 2010 will carry four new heat pipe modules to the station, which will be tested incrementally over the next few years.

Source: Rensselaer Polytechnic Institute (news : web)

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