Technology Focus: Test & Measurement

Instrument for Analysis of Greenland's Glacier Mills

NASA's Jet Propulsion Laboratory, Pasadena, California

A new instrument is used to study the inner workings of Greenland's glacier mills by riding the currents inside a glacier's moulin. The West Greenland Moulin Explorer instrument was deployed into a tubular shaft to autonomously record temperature, pressure, 3D acceleration, and location. It is built with a slightly positive buoyancy in order to assist in recovery.

The unit is made up of several components. A 3-axis MEMS (microelectromechanical systems) accelerometer with 0.001-g resolution forms the base of the unit. A pressure transducer is added that is capable of withstanding 500 psi (≈3.4 MPa), and surviving down to –40 °C. An Iridium modem sends out data every 10 minutes. The location is traced by a GPS (Global Positioning System) unit. This GPS unit is also used for recovery after the mission. Power is provided by a high-capacity lithium thionyl chloride D-sized battery. The accelerometer is housed inside a cylindrical, foot-long (≈30 cm) polyvinyl chloride (PVC) shell sealed at each end with acrylic. The pressure transducer is attached to one of these lids and a MEMS accelerometer to the other, recording 100 samples per second per axis.

This work was done by Alberto E. Behar, Jaret B. Matthews, and Hung B. Tran of the Jet Propulsion Laboratory; Konrad Steffen, Dan McGrath, and Thomas Phillips of the University of Colorado Boulder; and summer students Andrew Elliot, Sean O'Hern, Colin Lutz, Sujita Martin, and Henry Wang for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46514

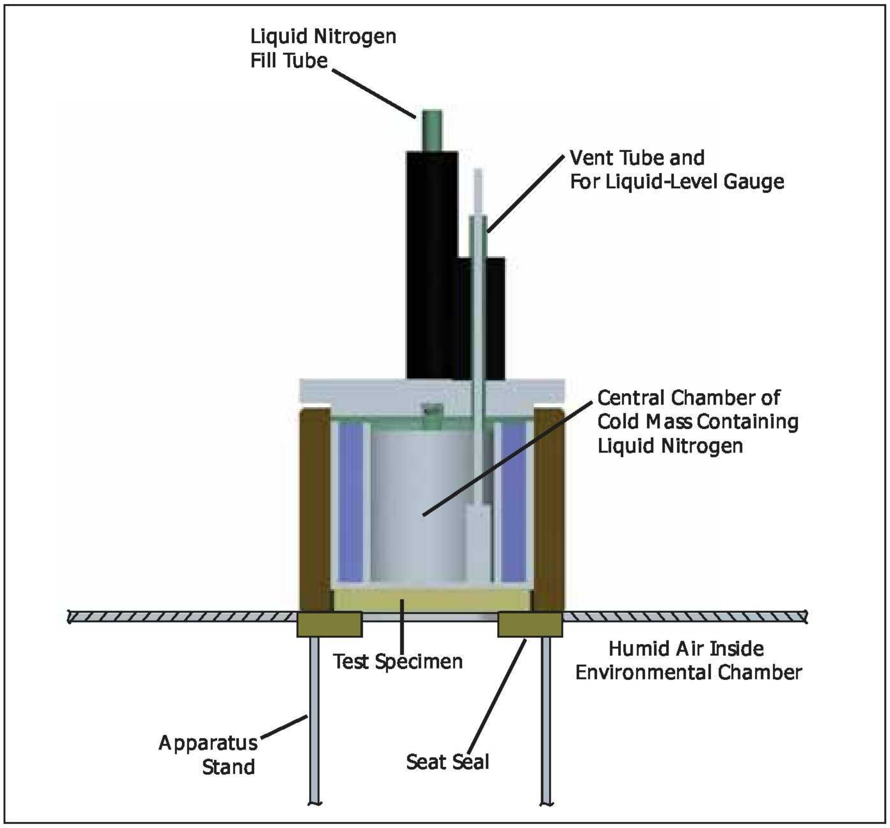
Cryogenic Moisture Apparatus

Testing for moisture uptake in materials can be performed under standardized cryogenic conditions.

John F. Kennedy Space Center, Florida

The Cryogenic Moisture Apparatus (CMA) is designed for quantifying the amount of moisture from the surrounding air that is taken up by cryogenic-tank-insulating material specimens while under typical conditions of use. More specifically, the CMA holds one face of the specimen at a desired low temperature (e.g., the typical liquid-nitrogen temperature of 77 K) while the opposite face remains exposed to humid air at ambient or near-ambient temperature. The specimen is weighed before and after exposure in the CMA. The difference between the "after" and "before" weights is determined to be the weight of moisture absorbed by the specimen.

Notwithstanding the term "cryogenic," the CMA is not limited to cryogenic applications: the low test temperature can be any temperature below ambient, and the specimen can be made of any material affected by moisture in air. The CMA is especially well suited for testing a variety of foam insulating materials, including those on the space-shuttle external cryogenic tanks, on other cryogenic vessels, and in refrigerators used for transporting foods, medicines, and other perishables. Testing is important because absorbed moisture not only adds weight but also, in combina-



The **Cryogenic Moisture Apparatus** imposes a low temperature on a central portion of the upper face of the specimen while the bottom face of the specimen is exposed to moist air at ambient or near-ambient temperature. This is a simplified view.

tion with thermal cycling, can contribute to damage that degrades insulating performance. Materials are changed internally when subjected to large sub-ambient temperature gradients.

The CMA (see figure) includes a cold mass in the form of an insulated vessel filled with liquid nitrogen or other suitable liquid at a desired below-ambient temperature. The 200-mm diameter specimen is placed over an opening on the top of an environmental chamber, wherein a temperature of 293 K and relative humidity of 90 percent are maintained in still air at ambient atmospheric pressure. The cold mass is placed atop the specimen, and a 152-mm-diameter cold surface at the bottom of the cold mass makes contact with the top surface of the specimen. The bottom surface of the specimen is exposed to the atmosphere inside the environmental chamber. Temperatures at the top and bottom surfaces of the specimen are measured by thermocouples and are monitored and recorded. The cold mass includes features that guard the outer edge surface of the specimen against substantial heat leakage and against intrusion of moisture so that the uptake of water or ice occurs only or primarily in the vertical, through-the-thickness direction. A typical test run lasts 8 hours from the beginning of cooldown, but test time can be changed as needed to achieve steady-state uptake of moisture.

This work was done by James Fesmire, Trent Smith, Robert Breakfield, and Kevin Boughner of Kennedy Space Center and Kenneth Heckle and Barry Meneghelli of Sierra Lobo, Inc. Further information is contained in a TSP (see page 1). KSC-13049

A Transportable Gravity Gradiometer Based on Atom Interferometry

Gravity field mapping technology enables more detailed study of dynamic Earth processes like climate change.

NASA's Jet Propulsion Laboratory, Pasadena, California

A transportable atom interferometer-based gravity gradiometer has been developed at JPL to carry out measurements of Earth's gravity field at ever finer spatial resolutions, and to facilitate high-resolution monitoring of temporal variations in the gravity field from ground- and flight-based platforms. Existing satellite-based gravity missions such as CHAMP and GRACE measure the gravity field via precise monitoring of the motion of the satellites; i.e. the satellites themselves function as test masses. JPL's quantum gravity gradiometer employs a quantum phase measurement technique, similar to that employed in atomic clocks, made possible by recent advances in laser cooling and manipulation of atoms. This measurement technique is based on atom-wave interferometry, and individual laser-cooled atoms are used as drag-free test masses.

The quantum gravity gradiometer employs two identical atom interferometers as precision accelerometers to measure the difference in gravitational acceleration between two points (Figure 1). By using the same lasers for the manipulation of atoms in both interferometers, the accelerometers have a common reference frame and non-inertial accelerations are effectively rejected as common-mode noise in the differential measurement of the gravity gradient. As a result, the dual atom interferometer-based gravity gradiometer allows gravity measurements on a moving platform,

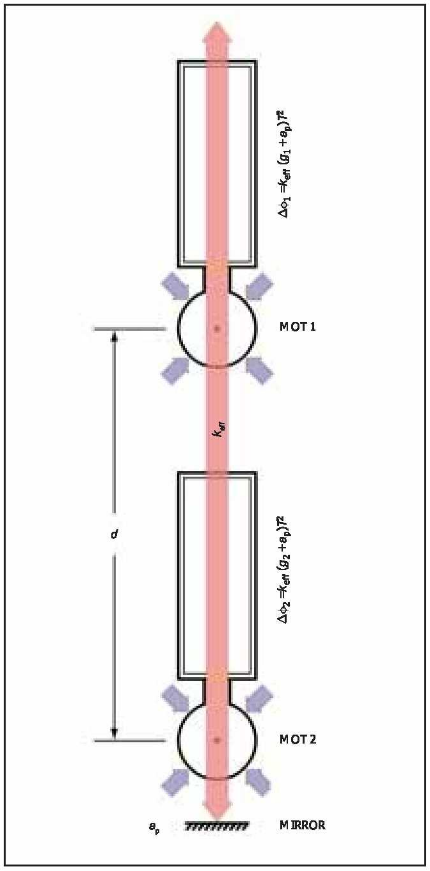


Figure 1. As shown in the schematic of the **Atom Interferometer-Based Gravity Gradiometer**, the dual atom interferometers measure the gravity gradient over the measurement baseline d. The platform accelerations a_p are effectively cancelled in the differential measurement. (T is the time between pulses, k_{eff} is the effective Raman laser wave number, and g is gravitational acceleration.)

Figure 2. The photograph shows the **Quantum Gravity Gradiometer** in the laboratory. The magnetic shields around the lower atom interferometer have been removed for clarity.