

mance to changes in the alignment and spacing of the mirrors. In addition, as a result of this choice of parameters, the light emerges from the cavity in a pattern that facilitates focusing of the light onto a possibly small photodetector.

The greatest advantage afforded by this design, relative to an on-axis design, is that one can use a narrow-band laser (bandwidth < 100 MHz), without need for complex, expensive equipment for precisely controlling the cavity length to manipulate or suppress resonances. Another advantage is reduction of optical feedback from the cavity to the laser and consequent elim-

ination of need for optical components to suppress such feedback.

Yet another advantage is removal of a major constraint on the alignment of the overall optical system: Instead of only one possible alignment geometry (the laser beam aligned with the optical axis of the cavity), one can choose any alignment for which there is a stable optical path through the cavity. As a result, alignment routine can be simplified and the instrument is less sensitive to vibration.

Currently, a product line of instruments is being developed based on the technology described above for high-

sensitivity, precision, and accurate gas measurements. Some applications that will benefit from this technology include atmospheric monitoring, chemical and biological agent detection, industrial process control, and medical diagnostics.

*This work was done by Anthony O'Keefe of Los Gatos Research for Ames Research Center.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14690-1.*

## Apparatus for Testing Flat Specimens of Thermal Insulation

An improved design affords flexibility for testing under diverse conditions.

*John F. Kennedy Space Center, Florida*

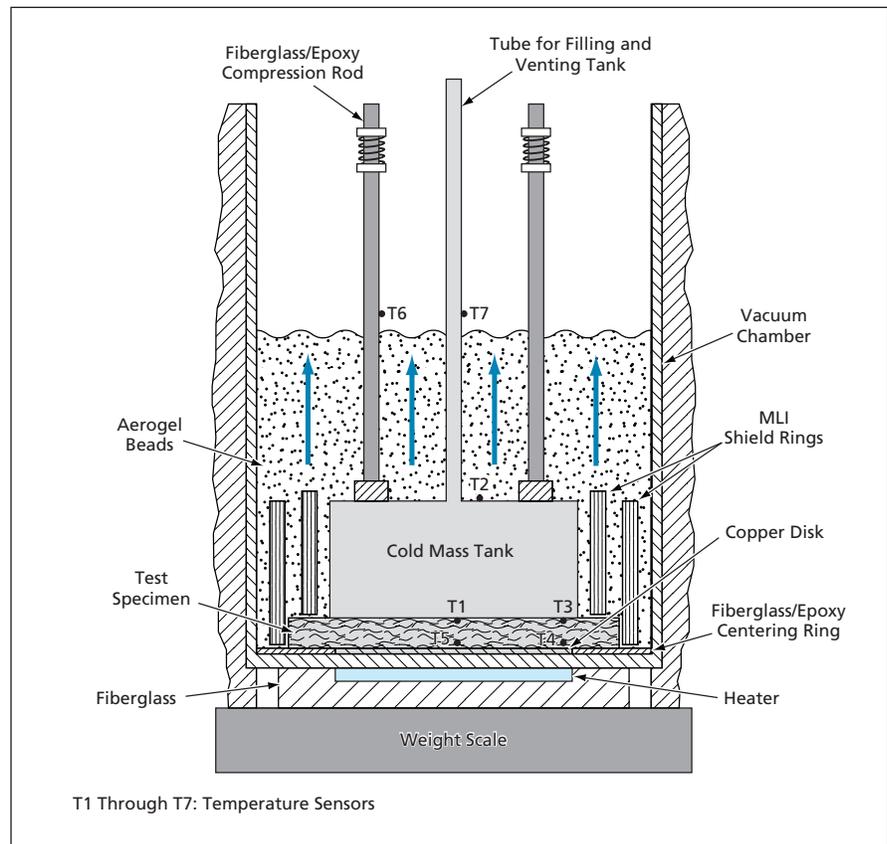
An apparatus has been developed to implement an improved method of testing flat-plate specimens of thermal-insulation materials for cryogenic application. The method includes testing under realistic use conditions that could include vacuum and mechanical loading at a pressure up to 70 psi ( $\approx 0.48$  MPa). The apparatus can accommodate a rigid or flexible specimen having thickness up to 1.25 in. ( $\approx 3.2$  cm) and diameters between 6 and 10 in. (about 15.2 and 25.4 cm, respectively). Typical test conditions include boundary temperatures between 77 K and 373 K and vacuum/interstitial gas filling at a pressure between  $10^{-6}$  torr ( $\approx 1.3 \times 10^{-4}$  Pa) and 760 torr (atmospheric pressure  $\approx 0.1$  MPa). The interstitial gas could be  $N_2$ , He,  $CO_2$ , or any other suitable gas to which the insulation is expected to be exposed in use. Relative to prior apparatuses and testing methods, this apparatus and the testing method that it implements offer advantages of relative simplicity and ease of use.

The basic principle of operation of the apparatus is that of boil-off calorimetry, using liquid nitrogen or any other suitable liquid that boils at a desired temperature below ambient temperature. Comparative rates of flow of heat through the thicknesses of the specimens (heat-leak rates) and apparent-thermal-conductivity values are obtained from tests of specimens. Absolute values of heat-leak rates and apparent thermal conductivities are computed from a combination of (1) the aforementioned comparative values and (2) calibra-

tion factors obtained by testing reference specimens of materials that have known thermal-insulation properties.

The apparatus includes a full complement of temperature sensors, a vacuum pump and chamber, a monitoring and

control system, and tools and fixtures that enable rapid and reliable installation and removal of specimens. A specimen is installed at the bottom of the vacuum chamber, and a cold-mass assembly that includes a tank is lowered into posi-



**A Specimen Is Sandwiched** between a cold mass tank containing liquid nitrogen and a heated copper plate. The apparent thermal conductivity of the specimen is determined from the liquid-nitrogen boil-off rate and the temperatures of the top and bottom specimen surfaces.

tion above and around the specimen (see figure). A spring-based compensating fixture helps to ensure adequate thermal contact with possibly irregular specimen surfaces. For a high-compression test, the springs can be replaced with spacers. A flat circular load cell at the bottom of the chamber measures the compressive load on the specimen. Once the desired compressive-load, temperature, and vacuum/gas-filling conditions are established, testing begins.

During a test, all measurements are recorded by use of a portable data-acquisition system and a computer.

The total heat-leak rate is measured and calculated as the boil-off flow rate multiplied by the latent heat of vaporization. The parasitic heat leak (to the side of the specimen and to the top and side of the cold-mass tank) is reduced to a small fraction of the total heat leak by use of a combination of multilayer-insulation (MLI) shield rings, reflective

film, a fiberglass/epoxy centering ring, and a bulk fill of aerogel beads. This combination eliminates the need for a cryogenic guard chamber used in a typical prior apparatus to reduce the parasitic heat leak.

*This work was done by James E. Fesmire of Kennedy Space Center and Stanislaw D. Augustynowicz of Dynacs, Inc. Further information is contained in a TSP (see page 1). KSC-12390*

## Quadrupole Ion Mass Spectrometer for Masses of 2 to 50 Da

H<sub>2</sub>, He, O<sub>2</sub>, and Ar can be quantitated at low concentrations in N<sub>2</sub>.

John F. Kennedy Space Center, Florida

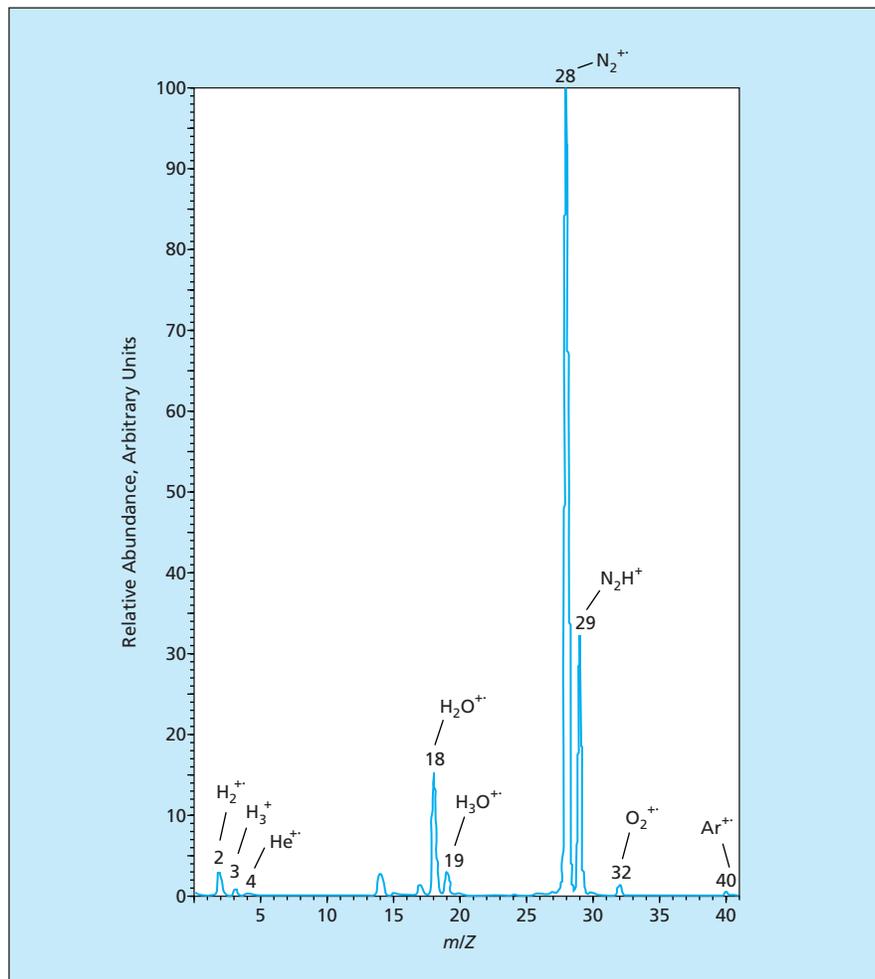
A customized quadrupole ion-trap mass spectrometer (QITMS) has been built to satisfy a need for a compact, rugged instrument for measuring small concentrations of hydrogen, helium, oxygen, and argon in a nitrogen atmosphere. This QITMS can also be used to perform quantitative analyses of other gases within its molecular-mass range, which is 2 to 50 daltons (Da). (More precisely, it can be used to perform quantitative analysis of gases that, when ionized, are characterized by  $m/Z$  ratios between 2 and 50, where  $m$  is the mass of an ion in daltons and  $Z$  is the number of fundamental electric charges on the ion.)

The QITMS was assembled mostly from commercial components. It includes a vacuum manifold, ion trap, and filament from a commercial ion-trap mass analyzer that produces ions within the ion trap by electron impact. Low-molecular-weight ions are effectively trapped when internal electron impact is used, despite the absence of a collision (buffer) gas. This internal-electron-impact assembly is compact, rugged, and suited for use in a miniaturized instrument. The assembly was modified to (1) increase the opening of the trap to the vacuum manifold in order to increase the rates of transport of analyte gases, (2) accommodate an ion high-vacuum gauge that measures the pressure in the open ion trap, and (3) replace an original gas-chromatograph-type transfer tube with a stainless-steel tube for introducing gas samples into the trap. A high vacuum is produced in the trap by means of a turbo-drag pump backed by either a diaphragm pump or a rotary-vane pump.

The electronic control and monitoring unit of the aforementioned commercial

ion-trap mass analyzer was replaced by a more capable control and monitoring unit from another commercial ion-trap mass analyzer, with minor changes in the electron-filament portion of the replacement unit to regulate emission of elec-

trons from the filament. With this modification, the electron-emission assembly produces a 200- $\mu$ A current of electrons at a kinetic energy of 90 eV. An electron multiplier from the second-mentioned commercial ion-trap mass analyzer was in-



This Mass Spectrum was obtained in an initial test of the QITMS, using a mixture of H<sub>2</sub>, He, O<sub>2</sub>, and Ar, each at a concentration of 1.25 percent in N<sub>2</sub>.