



Dual Cryogenic Capacitive Density Sensor

John F. Kennedy Space Center, Florida

A dual cryogenic capacitive density sensor has been developed. The device contains capacitive sensors that monitor two-phase cryogenic flow density to within $\pm 1\%$ accuracy, which, if temperature were known, could be used to determine the ratio of liquid to gas in the line. Two of these density sensors, located a known distance apart, comprise the sensor, providing some information on the velocity of the flow.

This sensor was constructed as a proposed mass flowmeter with high data acquisition rates. Without moving parts, this device is capable of detecting the density change within a two-

phase cryogenic flow more than 100 times a second. Detection is enabled by a series of two sets of five parallel plates with stainless steel, cryogenically rated tubing. The parallel plates form the two capacitive sensors, which are measured by electrically isolated digital electronics. These capacitors monitor the dielectric of the flow — essentially the density of the flow — and can be used to determine (along with temperature) the ratio of cryogenic liquid to gas. Combining this information with the velocity of the flow can, with care, be used to approximate the total two-phase mass flow.

The sensor can be operated at moderately high pressures and can be lowered into a cryogenic bath. The electronics have been substantially improved over the older sensors, incorporating a better microprocessor, elaborate ground loop protection and noise limiting circuitry, and reduced temperature sensitivity. At the time of this writing, this design has been bench tested at room temperature, but actual cryogenic tests are pending.

This work was done by Robert Youngquist of Kennedy Space Center and Carlos Mata, Peter Vokrot, and Robert Cox of ASRC Aerospace Corporation. Further information is contained in a TSP (see page 1). KSC-13058

Hail Monitor Sensor

This method of hail monitoring would be useful for the military and the commercial airline industry.

John F. Kennedy Space Center, Florida

Figure 1 shows damage to the space shuttle's external tank (ET) that was likely caused by a pea-sized hailstone. Because of the potential damage to the ET while exposed to the weather, it is important to remotely monitor the hail fall in the vicinity of the shuttle pad. If hail of sufficient size and quantity is detected by a hail-monitoring system, the ET would be subsequently thoroughly inspected for damage.

An inexpensive and simple hail monitor design has been developed that has a single piezoelectric ceramic disc and uses a metal plate as a sounding board. The structure is durable and able to withstand the launch environment. This design has several advantages over a multi-ceramic sensor, including reduced cost and complexity, increased durability, and improvement in impact response uniformity over the active surface. However, the most important characteristic of this design is the potential to use frequency discrimination between the spectrum created from raindrop impact and a hailstone impact. The sound of hail hitting a metal plate is distinctly different from the sound of rain hitting the same plate.

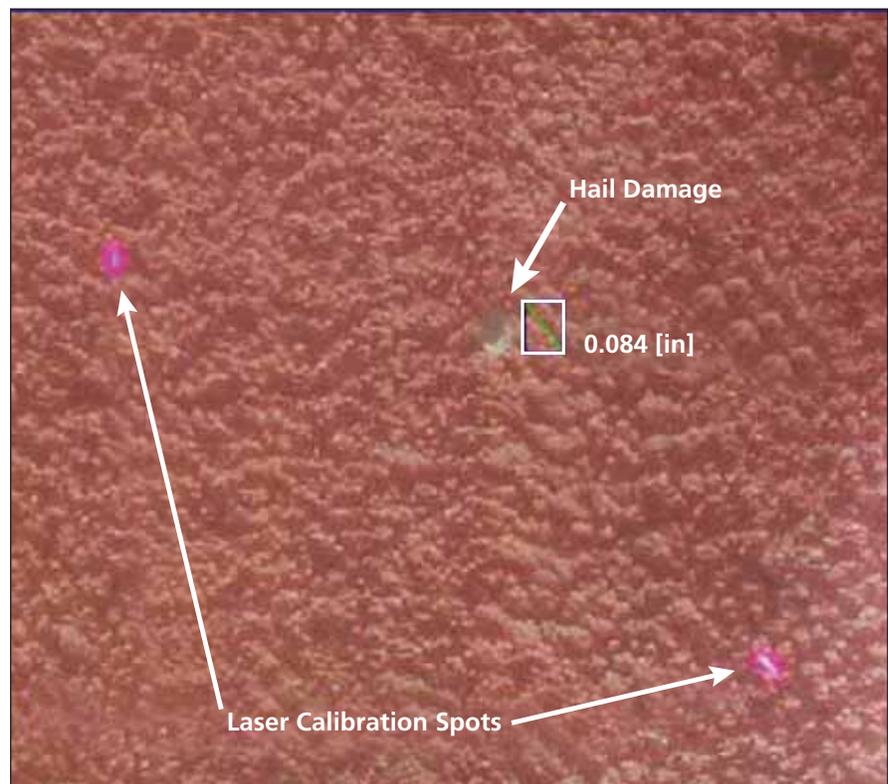


Figure 1. This Example of Hail Damage on the surface of the shuttle's external tank likely was caused by a pea-sized hailstone.

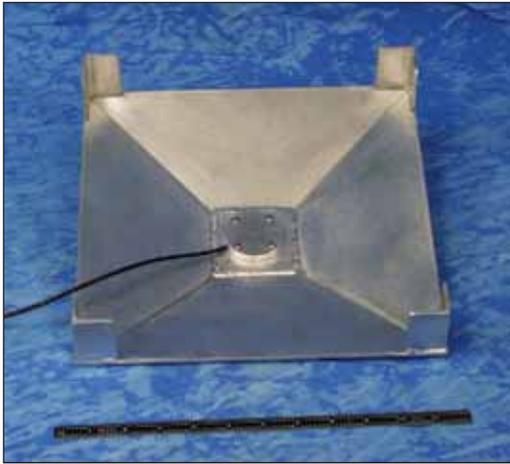


Figure 2. The prototype of the Hall Monitor Sensor uses a single piezoelectric ceramic disc with a metal plate as a sounding board. The concept was improved by forming a shallow pyramid structure so that hail would bounce away from the sensor and not be counted more than once.

This fortuitous behavior of the pyramid sensor may lead to a signal processing strategy, which is inherently more reliable than one depending on amplitude processing only.

The initial concept has been improved by forming a shallow pyramid structure so that hail is encouraged to bounce away from the sensor so as not to be counted more than once. The sloped surface also discourages water from collecting. Additionally, the final prototype version includes a mounting box for the piezo-ceramic, which is offset from the pyramid apex, thus helping to reduce non-uniform response (see Figure 2).

The frequency spectra from a single raindrop impact and a single ice ball impact have been compared. The most notable feature of the frequency resonant peaks is the ratio of the 5.2 kHz to 3.1 kHz components. In the case of a raindrop, this ratio is very small. But in the case of an ice ball, the ratio is roughly one third. This frequency signature of ice balls should provide a robust method for discriminating raindrops from hailstones.

Considering that hail size distributions (HSDs) and fall rates are roughly 1 percent that of rainfall, hailstone sizes range from a few tenths of a centimeter to several centimeters. There may be considerable size overlap between large rain and small hail. As hail occurs infrequently at KSC, the ideal HSD measurement sensor needs to have a collection area roughly 100 times greater than a raindrop-size distribution sensor or disdrometer. The sensitivity should be such that it can detect and count very small hail in the midst of intense rainfall consisting of large raindrop sizes. The dynamic range and durability should allow measurement of the largest hail sizes, and the operation and calibration strategy should consider the infrequent occurrence of hail fall over the KSC area.

This work was done by Robert Youngquist of Kennedy Space Center; William Haskell of Sierra Lobo, Inc.; and Christopher Immer, Bobby Cox, and John Lane of ASRC Aerospace. Further information is contained in a TSP (see page 1). KSC-12594

Miniature Six-Axis Load Sensor for Robotic Fingertip

Lyndon B. Johnson Space Center, Houston, Texas

A miniature load sensor has been developed as a prototype of tactile sensors that could fit within fingertips of anthropomorphic robot hands. The sensor includes a force-and-torque transducer in the form of a spring instrumented with at least six semiconductor strain gauges. The strain-gauge wires are secured to one side of an interface circuit board mounted at the base of the spring. This board protects the strain-gauge wires from damage that

could otherwise occur as a result of finger motions.

On the opposite side of the interface board, cables routed along the neutral axis of the finger route the strain-gauge output voltages to an analog-to-digital converter (A/D) board. The A/D board is mounted as close as possible to the strain gauges to minimize electromagnetic noise and other interference effects. The outputs of the A/D board are fed to a controller, wherein, by means of

a predetermined calibration matrix, the digitized strain-gauge output voltages are converted to three vector components of force and three of torque exerted by or on the fingertip.

This work was done by Myron A. Diftler and Toby B. Martin of Johnson Space Center; Michael C. Valvo and Dagoberto Rodriguez of Lockheed Martin Corp., and Mars W. Chu of Metrica, Inc. Further information is contained in a TSP (see page 1). MSC-23910-1

Improved Blackbody Temperature Sensors for a Vacuum Furnace

Through proper selection of materials, it is possible to satisfy severe requirements.

Marshall Space Flight Center, Alabama

Some improvements have been made in the design and fabrication of blackbody sensors (BBSs) used to measure the temperature of a heater core in a vacuum furnace. Each BBS consists of a ring of thermally conductive, high-melting-temperature material with two tantalum-sheathed thermocouples attached at diametrically opposite points. The name "blackbody sensor" reflects the basic

principle of operation. Heat is transferred between the ring and the furnace heater core primarily by blackbody radiation, heat is conducted through the ring to the thermocouples, and the temperature of the ring (and, hence, the temperature of the heater core) is measured by use of the thermocouples.

Two main requirements have guided the development of these BBSs:

(1) The rings should have as high an emissivity as possible in order to maximize the heat-transfer rate and thereby maximize temperature-monitoring performance and (2) the thermocouples must be joined to the rings in such a way as to ensure long-term, reliable intimate thermal contact. The problem of fabricating a BBS to satisfy these requirements is complicated by an application-specific prohibi-