Figure 1 depicts a hot-film sensor of this type. The substrate is primarily composed of high-temperature reusable shuttle insulation (HRSI), a lightweight (density = 352 kg/m^3), porous, ceramic material originally developed to protect the space shuttle from aerodynamic heating. A hard, non-porous coat of reaction-cured glass (RCG) extends over the face of the cylinder and about one-third of the way down the side providing a surface on which the metallic hot film and its leads can be deposited. Small-diameter [0.005 in. (0.127 mm)] thermocouple wires are routed through the HRSI. Small grooves in the end of the HRSI cylinder, form the lands of the thermocouples and are deep enough such that the wires lie flush with the HRSI surface prior to being coated with the RCG. The three thermocouple junctions are placed in a line. The substrates are placed in a machinable-ceramic sleeve that provides electrical isolation for the hot-film leads. Type R thermocouples must be used because the high firing temperature of the RCG coating precludes the use of the more-sensitive thermocouples of type K's.

The hot film itself is approximately 0.004 in. (≈0.102 mm) wide and 1/4 in. (6.35 mm) long. Fabrication of the hot film and its leads begins with hand painting the desired pattern using organometallic inks. The painted substrate is then heated in an oven, which removes the solvents from the ink leaving only a gold-alloy film (see Figure 1 photo). The sensor thermocouples provide feedback control to the oven. These techniques could be used for the fabrication of other temperature and heat-flux gauges on high-temperature ceramics.

Conjugate heat-transfer analyses were performed on different substrate materials in air at moderate velocity gradients (7,500 s^{-1}). For the composite ceramic substrate, the ratio of heat leaving the sensor via convection to total heat produced is about 4 times higher than for a quartz substrate. Figure 2 depicts steady-state temperature contours for quartz and a composite ceramic substrate. Preliminary bench tests comparing hot films on composite ceramic and machinable-ceramic substrates indicate that, at overheat ratios of 1.2 and in horizontal orientations, the higher conductivity machinable-ceramic substrates require over 2.5 times the power.

This work was done by Greg Noffz of **Dryden Flight Research Center**, *Daniel Leiser of Ames Research Center, Jim Bartlett of Langley Research Center, and Adrienne Lavine of UCLA. For further information, contact the Dryden Commercial Technology Office at (661) 276-3689. DRC-01-48*

Probe Without Moving Parts Measures Flow Angle

Flow angle is computed from forces measured by use of strain gauges.

Dryden Flight Research Center, Edwards, California

The measurement of local flow angle is critical in many fluid-dynamic applications, including the aerodynamic flight testing of new aircraft and flight systems. Flight researchers at NASA Dryden Flight Research Center have recently developed, flight-tested, and patented the force-based flow-angle probe (FLAP), a novel, force-based instrument for the measurement of local flow direction. Containing no moving parts, the FLAP may provide greater simplicity, improved accuracy, and increased measurement access, relative to conventional moving-vane-type flow-angle probes.

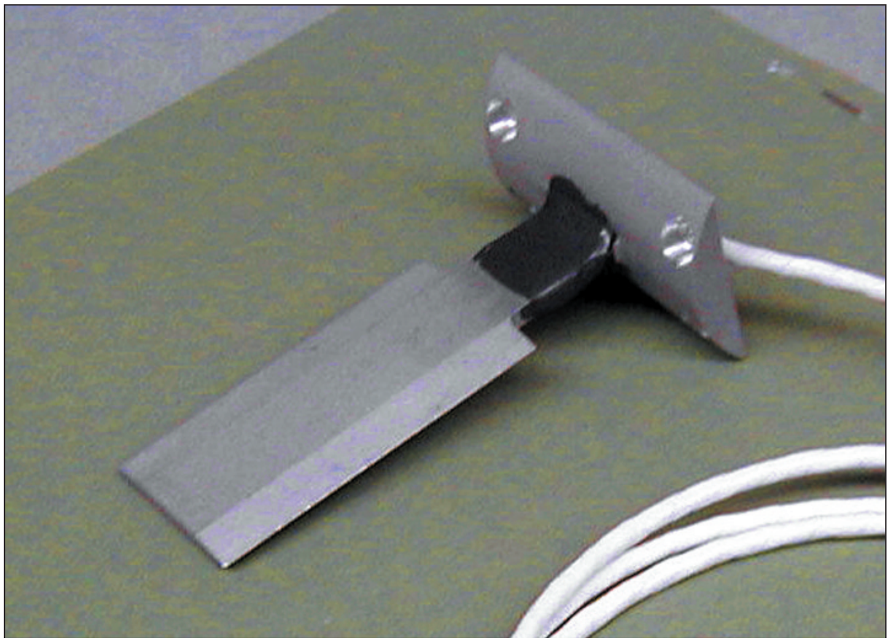

Figure 1. The **Prototype FLAP** was a fin instrumented with simple electrical-resistance strain gauges.

Forces in the FLAP can be measured by various techniques, including those that involve conventional strain gauges (based on electrical resistance) and those that involve more advanced strain gauges (based on optical fibers). A correlation is used to convert force-measurement data to the local flow angle. The use of fiber optics will enable the construction of a miniature FLAP, leading to the possibility of flow measurement in very small or confined regions. This may also enable the "tufting" of a surface with miniature FLAPs, capable of quantitative flow-angle measurements, similar to attaching yarn tufts for qualitative measurements.

The prototype FLAP was a small, aerodynamically shaped, low-aspect-ratio fin about 2 in. (≈5 cm) long, 1 in. (≈2.5 cm) wide, and 0.125 in. (≈0.3 cm) thick (see Figure 1). The prototype FLAP included simple electrical-resistance strain gauges for measuring forces. Four strain gauges were mounted on the FLAP; two on the upper surface and two on the lower surface. The gauges were connected to form a full Wheatstone bridge, configured as a bending bridge.

In preparation for a flight test, the prototype FLAP was mounted on the air-data boom of a flight-test fixture (FTF) on the NASA Dryden F-15B flight research airplane. The FTF is an aerodynamic fixture for flight-research experiments that is carried underneath the

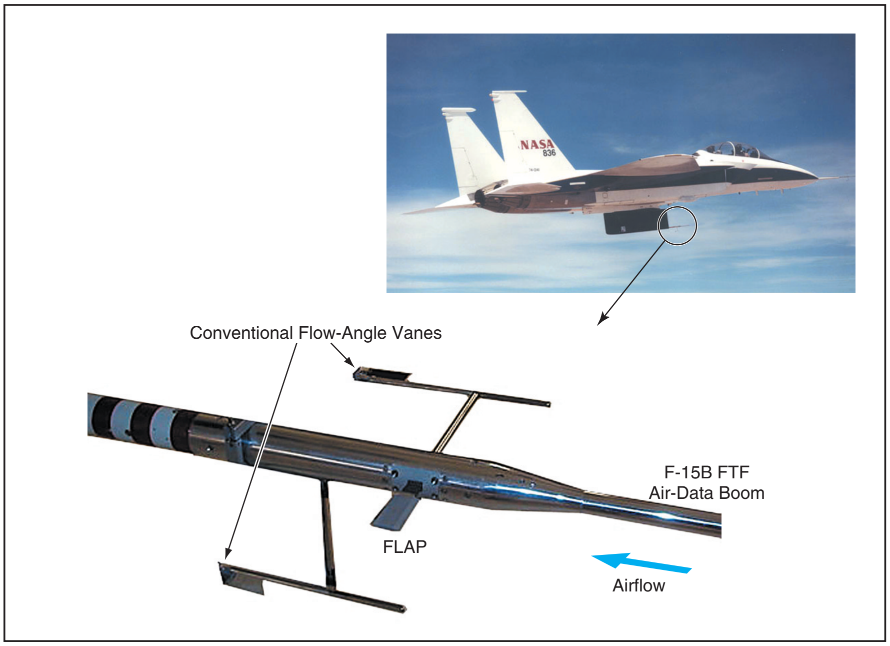

Figure 2. The **Air-Data Boom of the F-15B FTF** was used to carry the FLAP in a flight test.

F-15B fuselage (see Figure 2). Measurement data were collected as the FLAP was flown on the F-15B at subsonic and supersonic speeds up to mach 1.7 and altitudes up to 45,000 ft (≈13.7 km). FLAP data were also collected under high-angle-of-attack and high-vertical-acceleration flight conditions. The flight data analyzed to date have verified the feasibility of the FLAP concept.

In a second-generation FLAP now under development, the electrical-resistance-strain-gauge force-measurement system of the prototype FLAP is replaced with a fiber-optic-strain-gauge force-measurement system. This FLAP will also be flown on the NASA Dryden F-15B airplane.

This work was done by Stephen Corda and M. Jake Vachon of **Dryden Flight Research Center**. *Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Dryden Flight Research Center, Commercial Technology Office, (661) 276-3689. Refer to DRC-01-09.*

Detecting Conductive Liquid Leaking From Nonconductive Pipe

A capacitive detector is scanned over the ground above the pipe.

John F. Kennedy Space Center, Florida

A method that can be implemented with relatively simple electronic circuitry provides a capability for detecting leakage of an electrically conductive liquid from an electrically nonconductive underground pipe. Alternatively or in addition, the method can be applied to locate the pipe, whether or not there is a leak. Although the method is subject to limitations (some of which are described below), it is still attractive as an additional option for detecting leaks and locating pipes without need for extensive digging.

The method is based on capacitive coupling of an alternating electrical signal from the liquid to a portable electronic unit that resembles a metal detector. A signal voltage is applied to the liquid at some convenient point along the pipe: for example, the signal could be coupled into the liquid via an aboveground metal pipe fitting, the interior surface of which is in contact with the liquid. The signal is conducted through the liquid in the pipe; in the case of diffusive leak of liquid into the surrounding ground, the signal is conducted through the leak, into the portion of the adjacent ground that has become soaked with the liquid. (A drip leak cannot be detected by this method because there is no conductive path between the liquid inside and the liquid outside the pipe.)

The portable unit includes an electrically conductive plate connected to the input terminal of an amplifier. When the plate is brought near the pipe or the leaked liquid, a small portion of the signal power is coupled capacitively from the liquid to the plate. The user scans the plate near the ground surface to find the locus of maximum signal strength. The leak can be identified as a relatively wide area, contiguous with the location of the pipe, over which the signal is detectable.

In order for this method to work, the liquid must be sufficiently conductive, and must be significantly more conductive than the ground is. Thus, for example, the method does not work for pure water, which is nonconductive, and does not work where the ground has been soaked by a source other than a leak (e.g., heavy rain). It should be possible to apply this method to, for example, common polyvinyl chloride (PVC) pipes that contain impure water (e.g., swimming-pool water) leaking into fairly dry ground.

The resistance of a typical column of water in a PVC pipe is of the order of megohms. The combination of this order of magnitude of resistance with the order of magnitude of capacitance in a typical practical case dictates the use of a signal frequency or frequencies no higher than the low kilohertz range. Using the audibility of signals in the frequency range to make a virtue out of necessity, one could feed the detector-amplifier output to a set of earphones so that the user could keep visual attention focused on scanning the plate of the portable unit while listening for the signal.

This work was done by Robert C. Youngquist of **Kennedy Space Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-12255.