beams, each going to a photodiode having a spectral response that is known and that differs from the spectral responses of the other photodiodes. The outputs of these photodiodes are digitized and fed to a processor, which executes an algorithm that utilizes the known spectral responses to convert the photodiode outputs to obtain reference laser-power levels for the various wavelengths.

The transmitting optical coupler is mounted in (and sealed to) a hole in the pipe and is oriented at a slant with respect to the axis of the pipe. The transmitting optical coupler contains a collimating lens and a cylindrical lens that form the light emerging from the end of the fiber-optic cable into a fan-shaped

beam in a meridional plane of the pipe. Receiving optical couplers similar to the transmitting optical couplers are mounted in the same meridional plane at various longitudinal positions on the opposite side of the pipe, approximately facing the transmitting optical coupler along the same slant.

Light collected by each receiving optical coupler is sent, via a multimode fiber-optic cable, to a detector module similar to the reference detector module. The outputs of the photodiodes in each detector module are digitized and processed, similarly to those of the reference detector module, to obtain indications of the amounts of light of each wavelength scattered to the correspon-

ding receiving position. The value for each wavelength at each position is also normalized to the reference laser-power level for that wavelength. From these normalized values, the density and the mass flow rate of the fluid are estimated.

This work was done by John Wiley and Kevin Pedersen of Marshall Space Flight Center, Valentin Korman of Madison Research Corp., and Don Gregory of the University of Alabama at Huntsville.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32031-1.
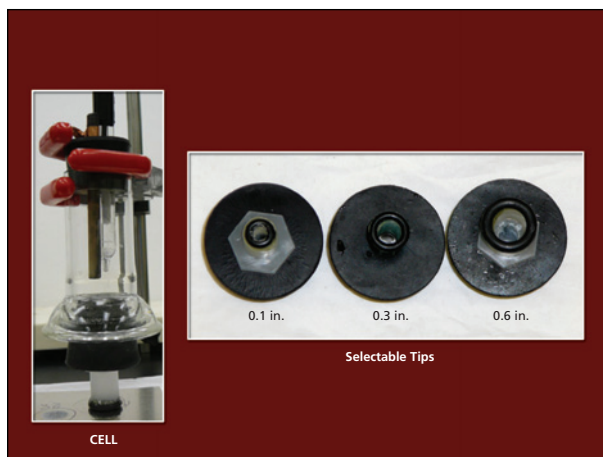
Selectable-Tip Corrosion-Testing Electrochemical Cell

The diameter and average depth of a corrosion pit can be selected.

John F. Kennedy Space Center, Florida

The figure depicts aspects of an electrochemical cell for pitting-corrosion tests of material specimens. The cell is designed to generate a region of corrosion having a pit diameter determined by the diameter of a selectable tip. The average depth of corrosion is controlled by controlling the total electric charge passing through the cell in a test. The cell is also designed to produce minimal artifacts associated with crevice corrosion.

There are three selectable tips, having diameters of 0.1 in. (0.254 cm), 0.3 in. (0.762 cm), and 0.6 in. (1.524 cm), respec-

CELL

Selectable Tips

0.1 in.   0.3 in.   0.6 in.

This **Corrosion-Testing Electrochemical Cell** is equipped with one of three selectable tips. Each tip features a different corrosion-pit diameter.

tively. The amount of electric charge needed to generate a corrosion pit having desired average depth h at a selected diameter d is given straightforwardly by

$$Q = F\rho\pi d^2 h/(4W)$$

F is the Faraday constant (the charge of one mole of electrons), ρ is the mass density of the specimen material, and W is the equivalent weight of the material (the mass of one mole of the material divided by the valence of the material).

This work was done by Janice Lomness and Paul Hintze of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13045

Piezoelectric Bolt Breakers and Bolt Fatigue Testers

Safer alternative to spacecraft explosive bolts may accelerate fatigue testing on Earth.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed family of devices for inducing fatigue in bolts in order to break the bolts would incorporate piezoelectric actuators into resonant fixtures as in ultrasonic/sonic drills/corers and similar devices described in numerous prior *NASA Tech Briefs* articles. These devices were originally intended primarily for use as safer, more-reliable, more-versatile alter-

natives to explosive bolts heretofore used to fasten spacecraft structures that must subsequently be separated from each other quickly on command during flight. On Earth, these devices could be used for accelerated fatigue testing of bolts.

Fatigue theory suggests that a bolt subjected to both a constant-amplitude dynamic (that is, oscillatory) stress and a

static tensile stress below the ultimate strength of the bolt material will fail faster than will a bolt subjected to only the dynamic stress. This suggestion would be applied in a device of the proposed type. The device would be designed so that the device and the bolt to be fatigue-tested or broken would be integral parts of an assembly (see figure).

The static tension in the tightened bolt would apply not only the clamping force to hold the joined structures (if any) together but also the compression necessary for proper operation of the piezo-electric actuators as parts of a resonant structural assembly. The constant-amplitude dynamic stress would be applied to the bolt by driving the piezoelectric actuators with a sinusoidal voltage at the resonance frequency of longitudinal vibration of the assembly. The amplitude of the excitation would be made large enough so that the vibration would induce fatigue in the bolt within an acceptably short time.

In the spacecraft applications or in similar terrestrial structural-separation applications, devices of the proposed type would offer several advantages over explosive bolts: Unlike explosive bolts, the proposed devices would be reusable, could be tested before final use, and would not be subject to catastrophic misfire. In fatigue-testing applications, devices of the proposed type would offer advantages of compactness and low cost, relative to conventional fatigue-testing apparatuses. In both structural-separation and fatigue-testing applications, bolts to be broken or tested could be instrumented with additional ultrasonic transducers for monitoring of pertinent physical properties and of fatigue failure processes.
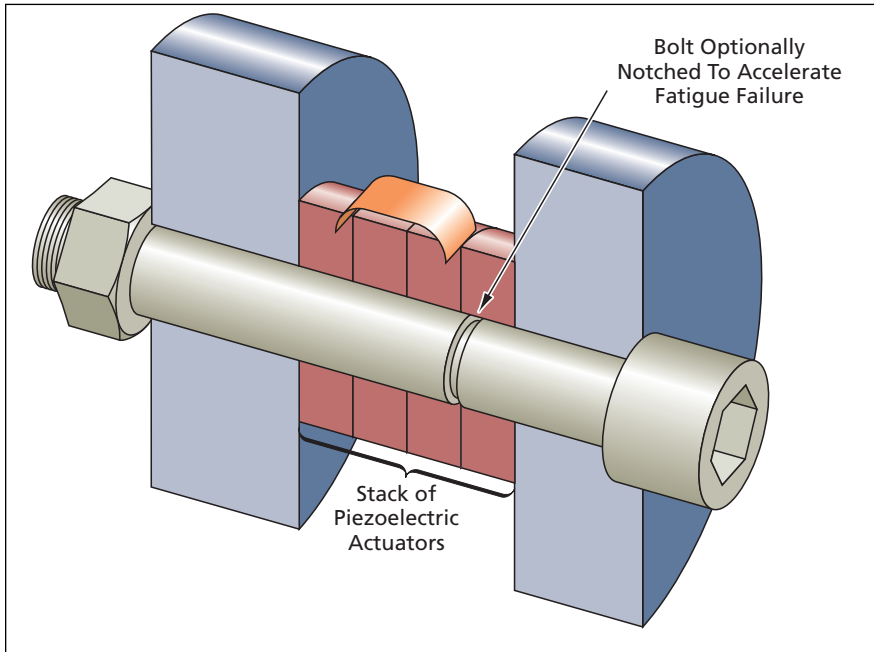
A **Bolt To Be Fatigue-Tested** or simply broken by accelerated fatigue would be tightened as an integral part of a resonant assembly that would also include piezoelectric actuators that would apply an oscillatory component of tensile stress.

Improved Measurement of B_{22} of Macromolecules in a Flow Cell
Invention helps researchers understand conditions that affect protein crystallization.

Marshall Space Flight Center, Alabama

An improved apparatus has been invented for use in determining the osmotic second virial coefficient of macromolecules in solution. In a typical intended application, the macromolecules would be, more specifically, protein molecules, and the protein solution would be pumped through a flow cell to investigate the physical and chemical conditions that affect crystallization of the protein in question.

Some background information is prerequisite to a meaningful description of the novel aspects of this apparatus. The osmotic second virial coefficient, customarily denoted by the algebraic symbol B_{22}, appears in the equation for the osmotic pressure of a macromolecular solution:

$$\pi = RT\rho(M - 1 + B_{22}\rho + \text{higher-order terms})$$

where π is the osmotic pressure, R is the ideal-gas constant, T is the absolute temperature, ρ is the concentration (more specifically, the mass density) of the macromolecule solute, and M is the mass of one mole of the solute. The osmotic second virial coefficient quantifies the degree of attraction or repulsion between the macromolecules under various solution conditions. Therefore, this coefficient is a valuable part of a method of determining optimum conditions for formulation of a protein solution and crystallization of the protein from the solution.

A method of determining B_{22} from simultaneous measurements of the static transmittance (taken as an indication of concentration) and static scattering of light from the same location in a flowing protein solution was published in 2004. The apparatus used to implement the method at that time included a dual-detector flow cell, which had two drawbacks:

• The amount of protein required for analysis of each solution condition was of the order of a milligram — far too large a quantity for a high-throughput analysis system, for which microgram or even nanogram quantities of protein per analysis are desirable.

• The design of flow cell was such that two light sources were used to probe different regions of the flowing solution. Consequently, the apparatus did not afford simultaneous measurements at the same location in the solution and, hence, did not guarantee an accurate determination of B_{22}.

This concludes the background information.

The present improved apparatus includes a flow cell wherein the required simultaneous transmittance and scattering measurements can be made at the same location. For the purpose of these measurements, light from two sources (a laser and an ultraviolet lamp) is delivered simultaneously to the designated location in the cell via a bifurcated optical fiber. The flow cell in this apparatus is narrower than that of the prior appa-