bearing, the instrument would include a flexural bearing that would be part of a metronomelike actuator. The measurement-signal and power connections between the electrode assembly and external instrumentation would be made via optical fibers that would flex with the flexural bearing.

The flexural bearing and actuator would be anchored to a stationary base, on which data-acquisition and power-supply electronic circuits would be mounted. In addition to the electrodes, the electrode assembly would contain electronic circuits for switching the electrical connections to the electrodes,

measuring the electric currents that flow between connected electrodes as the assembly rotates in the ambient electric field, digitizing the current measurements, and transmitting the digitized measurement signals to the data-acquisition circuitry via one of the optical fibers. Power would be transmitted from a light-emitting diode on the stationary base, via another optical fiber, to photovoltaic circuitry in the electrode assembly.

Because the flexural bearing, its actuator, and the electrode assembly taken together would constitute a resonant mechanical system like a metronome, little

power would be needed to maintain the large angular excursions needed to produce sufficiently large measurement signals. The precise nature of the actuator has not yet been determined; it seems likely that a magnetic drive could easily be implemented. The actuator could be equipped with a rotary position encoder, which could provide feedback for adjusting the excitation of the actuator to correct for small deviations of the rotational vibration from constant frequency and amplitude.

This work was done by Harold Kirkham of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30572

# Estimating Hardness From the USDC Tool-Bit Temperature Rise

Temperature rise during drilling is correlated with hardness of the drilled material.

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A method of real-time quantification of the hardness of a rock or similar material involves measurement of the temperature, as a function of time, of the tool bit of an ultrasonic/sonic drill corer (USDC) that is being used to drill into the material. The method is based on the idea that, other things being about equal, the rate of rise of temperature and the maximum temperature reached during drilling increase with the hardness of the drilled material.

In this method, the temperature is measured by means of a thermocouple embedded in the USDC tool bit near the drilling tip. [The concept of incorporating sensors into USDC tool bits was described in "Ultrasonic/Sonic Drill/Corers With Integrated Sensors" (NPO-20856), *NASA Tech Briefs*, Vol. 25, No. 1 (January 2001), page 38.] The hardness of the drilled material can then be determined through correlation of the temperature-rise-versus-time data with time-dependent temperature rises determined in finite-element simulations of, and/or experiments on, drilling at various known rates of advance or known power levels through materials of known hardness. The figure presents an example of empirical temperature-versus-time data for a particular 3.6-mm USDC bit, driven at an average power somewhat below 40 W, drilling through materials of various hardness levels.

The temperature readings from within a USDC tool bit can also be
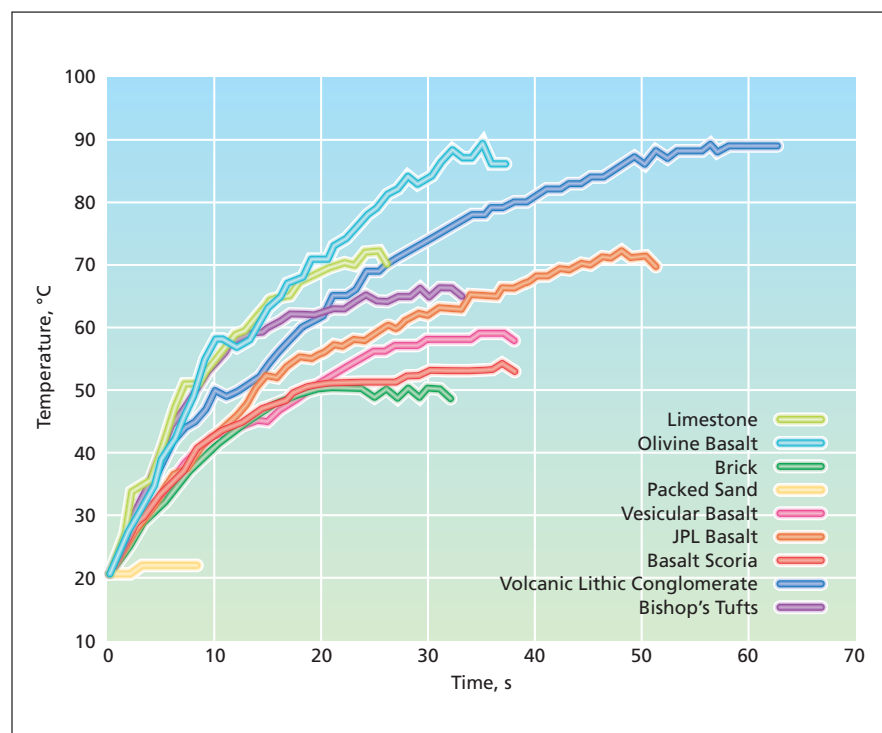
Temperature-Versus-Time data were obtained by use of a thermocouple embedded near a USDC tool bit drilling through materials of various hardness levels.

used for purposes other than estimating the hardness of the drilled material. For example, they can be especially useful as feedback to control the driving power to prevent thermal damage to the drilled material, the drill bit, or both. In the case of drilling through ice, the temperature readings could be used as a guide to maintain-

ing sufficient drive power to prevent jamming of the drill by preventing refreezing of melted ice in contact with the drill.

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