Physical Sciences

Smaller, Lower-Power Fast-Neutron Scintillation Detectors

There are numerous potential applications in scientific and safety-oriented monitoring of fast neutrons.

NASA's Jet Propulsion Laboratory, Pasadena, California

Scintillation-based fast-neutron detectors that are smaller and less power-hungry than mainstream scintillation-based fast-neutron detectors are undergoing development. There are numerous applications for such detectors in monitoring fast-neutron fluxes from nuclear reactors, nuclear materials, and natural sources, both on Earth and in outer space. A particularly important terrestrial application for small, low-power, portable fast-neutron detectors lies in the requirement to scan for nuclear materials in cargo and baggage arriving at international transportation facilities.

In the conventional method of detecting fast neutrons (by which is meant neutrons having kinetic energies greater than about 10 keV), the neutrons are first decelerated, by use of moderator materials (typically, paraffin or polyethylene) to near thermal kinetic energies, in order to exploit the fact that the cross sections for interactions of neutrons with other nuclei are largest at low kinetic energies. To be useful for this purpose, moderators must be several inches (of the order of 10 cm) thick. In addition, one must use gas-filled detector tubes containing electrodes to which high bias voltages are applied. Hence, conventional fast-neutron detectors are inherently bulky and heavy.

Several decades ago, scintillation-based detectors were introduced as smaller alternatives to conventional fast-neutron detectors. A scintillation detector of this type includes a photomultiplier tube that monitors a block of a scintillator material (typically, a crystal or a plastic containing a hydrogen rich scintillation dye). A scintillation pulse occurs when a fast neutron knocks a proton in the scintillation material and some of the kinetic energy of the decelerating proton excites luminescence. Although the use of a block of scintillator material is a step toward miniaturization, a photomultiplier tube is still a bulky, high-power device.

The present development of miniature, low-power scintillation-based fast-neutron detectors exploits recent advances in the fabrication of avalanche photodiodes (APDs). Basically, such a detector includes a plastic scintillator, typically between 300 and 400 μm thick with very thin silver mirror coating on all its faces except the one bonded to an APD (see figure). All photons generated from scintillation are thus internally reflected and eventually directed to the APD. This design affords not only compactness but also tight optical coupling for utilization of a relatively large proportion of the scintillation light. The combination of this tight coupling and the avalanche-multiplication gain (typically between 750 and 1,000) of the APD is expected to have enough sensitivity to enable monitoring of a fast-neutron flux as small as 1,000 $cm^{-2}s^{-1}$. Moreover, pulse-height analysis can be expected to provide information on the kinetic energies of incident neutrons. It has been estimated that a complete, fully developed fast-neutron detector of this type, would be characterized by linear dimensions of the order of 10 cm or less, a mass of no more than about 0.5 kg, and a power demand of no more than a few watts.

This work was done by Jagdish Patel and Brent Blaes of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Refer to NPO-41345, volume and number of this NASA Tech Briefs *issue, and the page number.*

Rotationally Vibrating Electric-Field Mill

The disadvantages of rotary couplings in conventional field mills could be avoided.

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A proposed instrument for measuring a static electric field would be based partly on a conventional rotating-split-cylinder or rotating-split-sphere electric-field mill. However, the design of the proposed instrument would overcome the difficulty, encountered in conventional rotational field mills, of transferring measurement signals and power via either electrical or fiber-optic rotary couplings that must be aligned and installed in conjunction with rotary bearings. Instead of being made to rotate in one direction at a steady speed as in a conventional rotational field mill, a split-cylinder or split-sphere electrode assembly in the proposed instrument would be set into rotational vibration like that of a metronome. The rotational vibration, synchronized with appropriate rapid electronic switching of electrical connections between electric-current-measuring circuitry and the split-cylinder or split-sphere electrodes, would result in an electrical measurement effect equivalent to that of a conventional rotational field mill.

The figure depicts a version of the proposed instrument, the electrode assembly of which would include a hollow metal hemisphere split into four electrodes. Instead of a conventional rotary 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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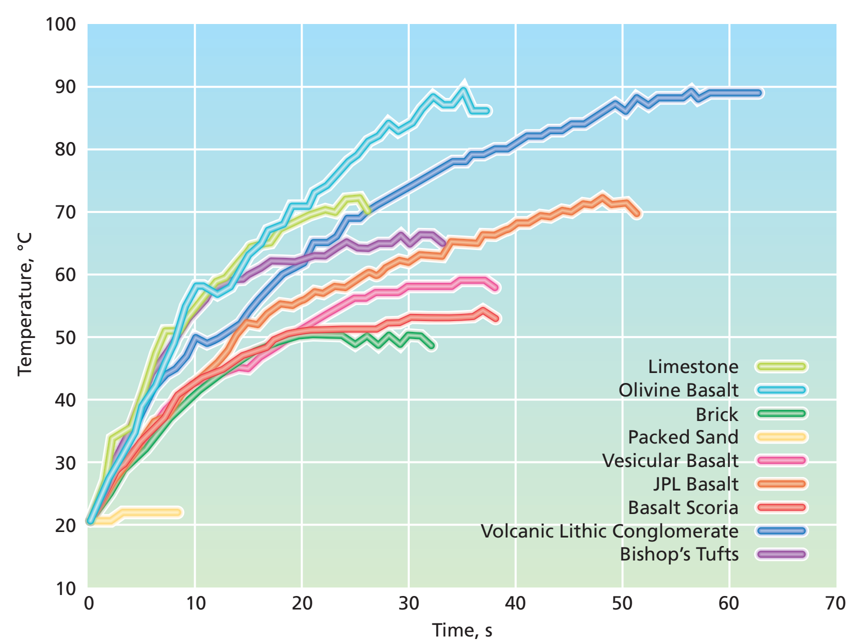
A method of real-time quantification of the hardness of a rock or similar material involves measurement of the temperature, as a function of time, of the tool bit of an ultrasonic/sonic drill corer (USDC) that is being used to drill into the material. The method is based on the idea that, other things 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.



Temperature-Versus-Time data were obtained by use of a thermocouple embedded near a USDC tool bit drilling through materials of various hardness levels.

The temperature readings from within a USDC tool bit can also be 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 maintaining sufficient drive power to prevent jamming of the drill by preventing refreezing of melted ice in contact with the drill.

This work was done by Yoseph Bar-Cohen and Stewart Sherrit of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-40132