Physical Sciences

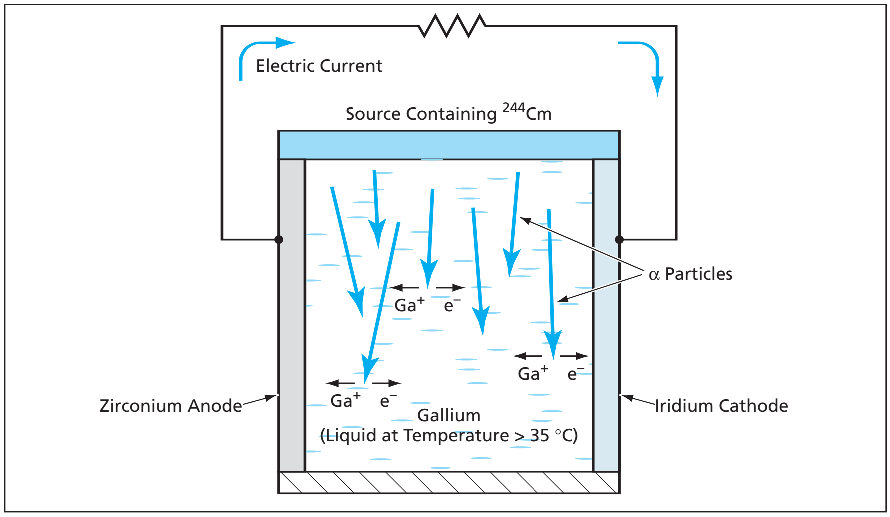
Alpha-Voltaic Sources Using Liquid Ga as Conversion Medium

These units would offer long life and high energy-conversion efficiency.

NASA's Jet Propulsion Laboratory, Pasadena, California

A family of proposed miniature sources of power would exploit the direct conversion of the kinetic energy of α particles into electricity. In addition to having long operational lives, these sources are expected to operate with energy-conversion efficiencies from 70 to 90 percent.

A power source as proposed (see figure) would be an electrolytic cell in which liquid gallium would serve as both an electrolyte and an energy-conversion medium. The cell would contain an iridium cathode and a zirconium anode. The α particles, each with a kinetic energy ~5.8 MeV, would be emitted by radioactive decay of ^{244}Cm, which has a half-life of 18 years. The ^{244}Cm source would be positioned so that the α particles would enter the liquid gallium, where their kinetic energy would be dissipated mostly through ionization of Ga atoms, creating Ga^+ ions and free electrons. The electrons would be collected by iridium cathode, and the Ga^+ ions would be neutralized at the zirconium cathode by electrons returning after flowing through an external circuit.



Liquid Gallium in an Electrolytic Cell would be ionized by impinging α particles. The resulting electric charges would be collected at the electrodes.

Gallium is a candidate for use as the electrolyte and the energy-conversion medium because in the liquid state it is a semimetal: its electrical conductivity is greater than that of a typical semiconductor but small in comparison with the conductivities of metals. Consequently, in liquid gallium, electrons and Ga^+ can exist without immediate recombination and can be moved by electric fields. It is expected that electric fields, resulting at least partly from the difference between the work functions of the electrode metals, would move the electrons and ions to their respective electrodes. The open-circuit potential of the cell is expected to be 1.62 V — equal to the difference between the work functions of iridium and zirconium.

Unlike in a solid-state energy conversion medium, the impingement of energetic α particles would not give rise to displacement damage in the liquid gallium. Hence, the cell should have a long life, limited only by the half-life of ^{244}Cm. A cell having a volume less than 25 mm^3, containing 1 curie of ^{244}Cm (the curie is a unit of radioactivity equal to 3.7×10^{10} disintegrations per second) is expected to deliver a current between 7 and 12 mA, which, at the expected open-circuit potential, would provide a power in the approximate range of 11 to 20 mW.

This work was done by Jagdish U. Patel, Jean-Pierre Fleurial, and G. Jeffrey Snyder of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL at (818) 354-7770. Refer to NPO-30322.

Ice-Borehole Probe

The art of borehole imaging has been extended to deep, cold, wet, high-pressure environments.

NASA's Jet Propulsion Laboratory, Pasadena, California

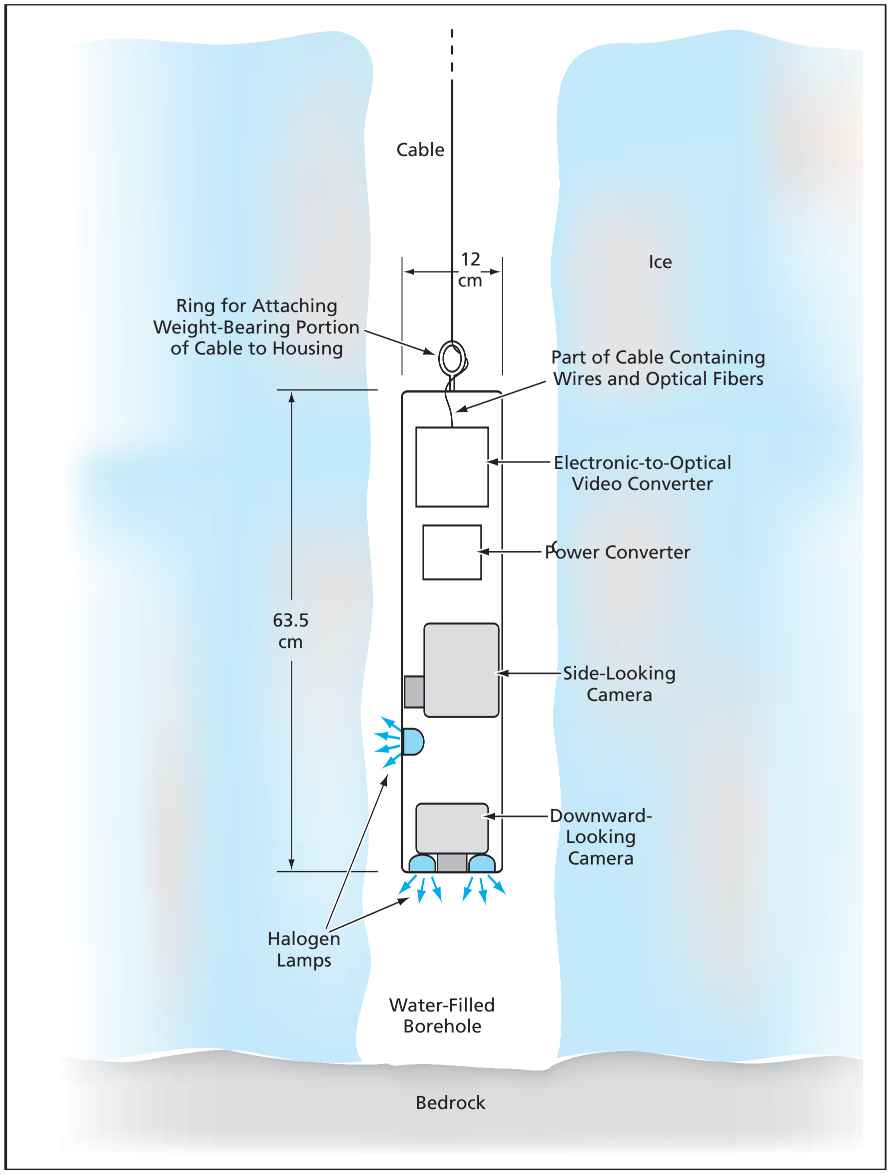
An instrumentation system has been developed for studying interactions between a glacier or ice sheet and the underlying rock and/or soil. Prior borehole imaging systems have been used in well-drilling and mineral-exploration applications and for studying relatively thin valley glaciers, but have not been used for studying thick ice sheets like those of Antarctica.

The system includes a cylindrical imaging probe that is lowered into a hole that has been bored through the ice to the ice/bedrock interface by use of an established hot-water-jet technique. The images acquired by the cameras yield information on the movement of the ice relative to the bedrock and on visible features of the lower structure of the ice sheet, including ice layers formed at different times, bubbles, and mineralogical inclusions. At the time of reporting the information for this article, the system was just deployed in two boreholes on the Amery ice shelf in East Antarctica and after successful 2000–2001 deployments in 4 boreholes at Ice Stream C, West Antarctica, and in 2002 at Black Rapids Glacier, Alaska.

The probe is designed to operate at temperatures from –40 to +40 °C and to withstand the cold, wet, high-pressure [130-atm (13.20-MPa)] environment at the bottom of a water-filled borehole in ice as deep as 1.6 km. A current version is being outfitted to service 2.4-km-deep boreholes at the Rutford Ice Stream in West Antarctica. The probe (see figure) contains a side-looking charge-coupled-device (CCD) camera that generates both a real-time analog video signal and a sequence of still-image data, and contains a digital videotape recorder. The probe also contains a downward-looking CCD analog video camera, plus halogen lamps to illuminate the fields of view of both cameras. The analog video outputs of the cameras are converted to optical signals that are transmitted to a surface station via optical fibers in a cable. Electric power is supplied to the probe through wires in the cable at a potential of 170 VDC. A DC-to-DC converter steps the supply down to 12 VDC for the lights, cameras, and image-data-transmission circuitry. Heat generated by dissipation of electric power in the probe is removed simply by conduction through the probe housing to the adjacent water and ice.

One of the new, creative, and very important attributes of this system is its ability to provide the scientist/operator with direct real-time imaging of the ice in front of the cameras. This allows real-time interaction of a knowledgeable observer and control over when to stop to study further, as well as the two-way command and control that lets one zoom/focus into the ice structure to get "internal" versus wall-structure views at a 100- to 200-mm scale.

The probe is lowered into the borehole by using the cable as a tether. The cable is 1.6 km long and is wound on a spool about 0.9 m in diameter. The spool is rotated by a three-phase AC motor to pay out or pull in the cable at a speed of about 1 m/s. In addition to the wires for transmitting power and the optical fibers for transmitting data,



A **Cylindrical Probe Housing** containing two cameras is lowered to the bottom of a borehole in ice to acquire images of ice structures, inclusions, and ice/bedrock interactions.

the cable contains strengthening members and includes a waterproof cover. The cable, the spool, the motor, and a sled on which the spool and motor are mounted have a total mass of 180 kg. Other equipment in the surface station includes the following: two video monitors that display the current video feeds from each camera; two digital video tape recorders that digitize the incoming analog video images and store the resulting data for subsequent analysis; and a computer that is used to control the operation of the probe and, after image data have been acquired, to digitally manipulate the images and analyze their contents.

All the image data are time-tagged to enable detailed correlations of images during *post factum* analysis. To assist an operator in subsequently locating unique image features, the real-time video display contains subwindows that indicate depth and time. The highest-quality digital images are recorded by a digital videotape recorder within the side-looking camera. The videotape is removed from the probe after the probe has been returned to the surface station. Time tagging provides a direct correlation between these taped images and the ones recorded in the surface station.

This work was done by Alberto Behar, Frank Carsey, Arthur Lane, and Herman Engelhardt of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1). NPO-40500*