Replaceable Sensor System for Bioreactor Monitoring

An instrument is capable of detecting and monitoring biological media constituents in a spaceflight bioreactor.

Lyndon B. Johnson Space Center, Houston, Texas

A sensor system was proposed that would monitor spaceflight bioreactor parameters. Not only will this technology be invaluable in the space program for which it was developed, it will find applications in medical science and industrial laboratories as well.

Using frequency-domain-based fluorescence lifetime technology, the sensor system will be able to detect changes in fluorescence lifetime quenching that results from displacement of fluorophore-labeled receptors bound to target ligands. This device will be used to monitor and regulate bioreactor parameters including glucose, pH, oxygen pressure (pO_2), and carbon dioxide pressure (pCO_2). Moreover, these biosensor fluorophore receptor-quenching complexes can be designed to further detect and monitor for potential biohazards, bioproducts, or bioimpurities.

Biosensors used to detect biological fluid constituents have already been developed that employ a number of strategies, including invasive microelectrodes (e.g., dark electrodes), optical techniques including fluorescence, and membrane permeable systems based on osmotic pressure. Yet the longevity of any of these sensors does not meet the demands of extended use in spacecraft habitat or bioreactor monitoring. It was therefore necessary to develop a sensor platform that could determine not only fluid variables such as glucose concentration, pO_2, pCO_2, and pH but can also regulate these fluid variables with controlled feedback loop.

To accommodate the inevitable failure of sensing elements, a biosensor array must be noninvasive and interchangeable — something missing in the current state of the art. Robust, compact, *in-situ* biosensor arrays that are easy to use and self-contained are needed for the onboard testing and monitoring of bioreactor parameters. In a miniaturized frequency-domain lifetime fluorescence (fLF) system, sensor arrays can be integrated into a "dead leg" where the desired assays of bioreactor constituents can be analyzed and results can be sent to a feedback control of regulatory valves that will release nutrients and maintain a constant bioenvironment for cell or tissue culture growth.

The sensor array and dead-leg test solution must be designed so that they are interchangeable for the inevitable requirement of sensor replacement. This design will take into account sterilization considerations as well as the ease with which a part can be replaced in order to minimize the use of astronaut time. The dead leg will allow a small volume of sample to be directed over the fLF sensor surface in order to collect multicomponent emissions and analyze them for different constituents. The biosensor system will also contain feedback controls to the feed lines of the bioreactor, thus providing autonomous operation.

The final fLF sensor system will contain a fully optimized sensor array that can be interfaced with the dead leg of a bioreactor or bioenvironment where current fLF analysis can be performed repeatedly and then replaced when sensor failure occurs. The fLF has a proven track record and the small dimensions needed to accommodate removable and interchangeable interfacings with the bioreactor/bioenvironment. Scientists believe that an even smaller dimension system can be developed for interfacing directly with the bioreactor. This sensor platform, which will be built around this dead-leg sample analysis segment, will be used for preflight testing/evaluation as a solution to bioreactor environment control and will also be marketed in a development program for use in bioreactor control in the biopharmaceutical and medical industries.

The development of this multi-analyte biosensor system has broad commercial applications in the biopharmaceutical industry where genetically engineered drugs are produced by bioreactors. In addition to its use for bioreactor monitoring, this fLF biosensor technology will be useful for biosensor applications including detection of toxins, dangerous chemicals, and hazardous environmental agents. In addition to monitoring bioreactor parameters during long spaceflights of the future, this system can be used to monitor for biohazards to ensure astronaut safety.

This work was done by Mike Mayo, Steve Savoy, and John Bruno of Systems & Processes Engineering Corporation for **Johnson Space Center**. *For further information, contact the Johnson Technology Transfer Office at (281) 483-3809.*
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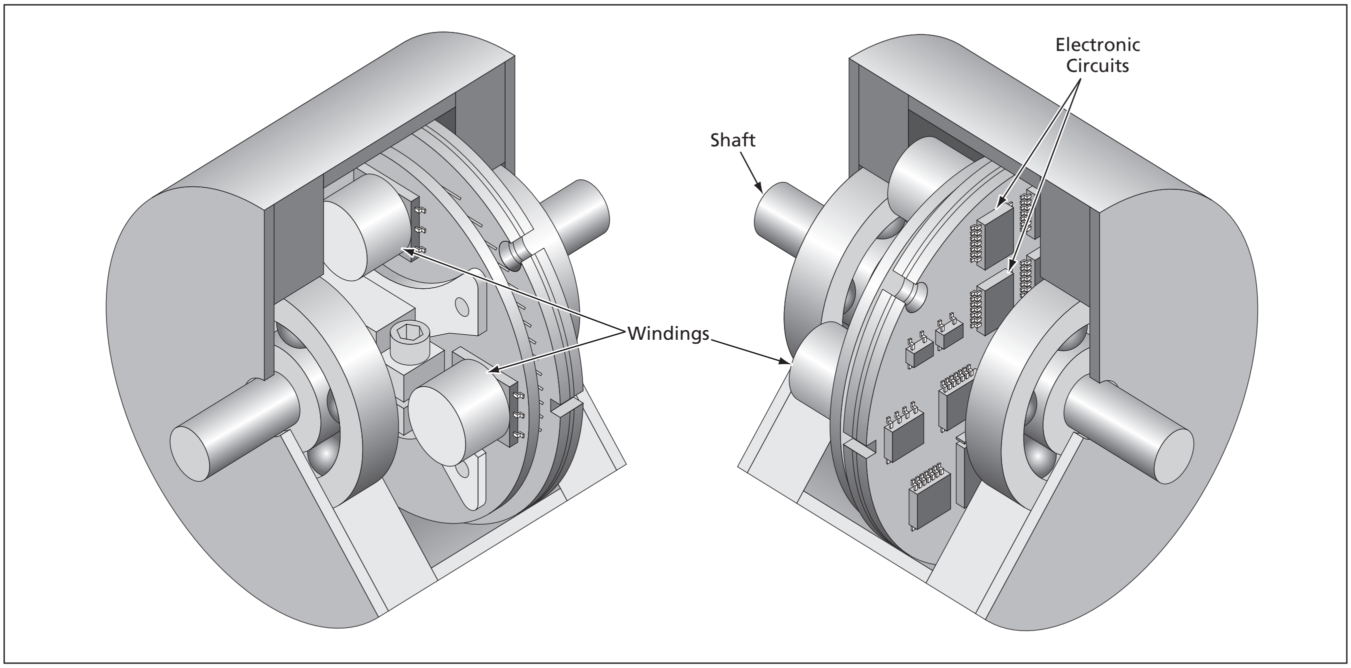
Unitary Shaft-Angle and Shaft-Speed Sensor Assemblies

All necessary mechanical and electronic components are packaged together in compact units.

Marshall Space Flight Center, Alabama

The figure depicts a unit that contains a rotary-position or a rotary-speed sensor, plus electronic circuitry necessary for its operation, all enclosed in a single housing with a shaft for coupling to an external rotary machine. This rotation-sensor unit is complete: when its shaft is mechanically connected to that of the rotary machine and it is supplied with electric power, it generates an output signal directly indicative of the rotary position or speed, without need for additional processing by other circuitry. The incorporation of all of the necessary excitatory and readout circuitry into the housing (in contradistinction to using externally located excitatory and/or readout circuitry) in a compact arrange-



Transducers and Readout Electronic Circuits are parts of a sensor assembly contained in a single housing.

ment is the major difference between this unit and prior rotation-sensor units.

The sensor assembly inside the housing includes excitatory and readout integrated circuits mounted on a circular printed-circuit board. In a typical case in which the angle or speed transducer(s) utilize electromagnetic induction, the assembly also includes another circular printed-circuit board on which the transducer windings are mounted. A sheet of high-magnetic-permeability metal ("mu metal") is placed between the winding board and the electronic-circuit board to prevent spurious coupling of excitatory signals from the transducer windings to the readout circuits.

The housing and most of the other mechanical hardware can be common to a variety of different sensor designs. Hence, the unit can be configured to generate any of variety of outputs by changing the interior sensor assembly. For example, the sensor assembly could contain an analog tachometer circuit that generates an output proportional (in both magnitude and sign or in magnitude only) to the speed of rotation.

This work was done by Dean C. Alhorn, David E. Howard, and Dennis A. Smith of **Marshall Space Flight Center**. *Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 6,313,624). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31238.

Arrays of Nano Tunnel Junctions as Infrared Image Sensors

High detectivity and rapid response would be attainable at room temperature.

NASA's Jet Propulsion Laboratory, Pasadena, California

Infrared image sensors based on high-density rectangular planar arrays of nano tunnel junctions have been proposed. These sensors would differ fundamentally from prior infrared sensors based, variously, on bolometry or conventional semiconductor photodetection.

Infrared image sensors based on conventional semiconductor photodetection must typically be cooled to cryogenic temperatures to reduce noise to acceptably low levels. Some bolometer-type infrared sensors can be operated at room temperature, but they exhibit low detectivities and long response times, which limit their utility. The proposed infrared image sensors could be operated at room temperature without incurring excessive noise, and would exhibit high detectivities and short response times. Other advantages would include low power demand, high resolution, and tailorability of spectral response.

Neither bolometers nor conventional semiconductor photodetectors, the basic detector units as proposed would partly resemble rectennas. Nanometer-scale tunnel junctions would be created by crossing of nanowires with quantum-mechanical-barrier layers in the form of thin layers of electrically insulating material between them (see figure). A microscopic dipole antenna sized and shaped to respond maximally in the infrared wavelength range that one seeks to detect would be formed integrally with the nanowires at each junction. An incident signal in that wavelength range would become coupled into the antenna and, through the antenna, to the junction. At the junction, the flow of electrons between the crossing wires would be dominated by quantum-mechanical tunneling rather than thermionic emission. Rela-