Bio-Medical

Two Devices for Removing Sludge From Bioreactor Wastewater

These devices can operate continuously and are self-cleaning.

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Two devices — a magnetic separator and a special filter denoted a self-regenerating separator (SRS) — have been developed for separating sludge from the stream of wastewater from a bioreactor. These devices were originally intended for use in microgravity, but have also been demonstrated to function in normal Earth gravity.

The magnetic separator (see Figure 1) includes a thin-walled nonmagnetic, stainless-steel cylindrical drum that rotates within a cylindrical housing. The wastewater enters the separator through a recirculation inlet, and about 80 percent of the wastewater flow leaves through a recirculation outlet. Inside the drum, a magnet holder positions strong permanent magnets stationary and, except near a recirculation outlet, close to the inner drum surface. To enable magnetic separation, magnetite (a ferromagnetic and magnetically soft iron oxide) powder is mixed into the bioreactor wastewater. The magnetite becomes incorporated into the sludge by condensation, onto the powder particles, of microbe flocks that constitute the sludge. As a result, the magnets inside the drum magnetically attract the sludge onto the outer surface of the drum.

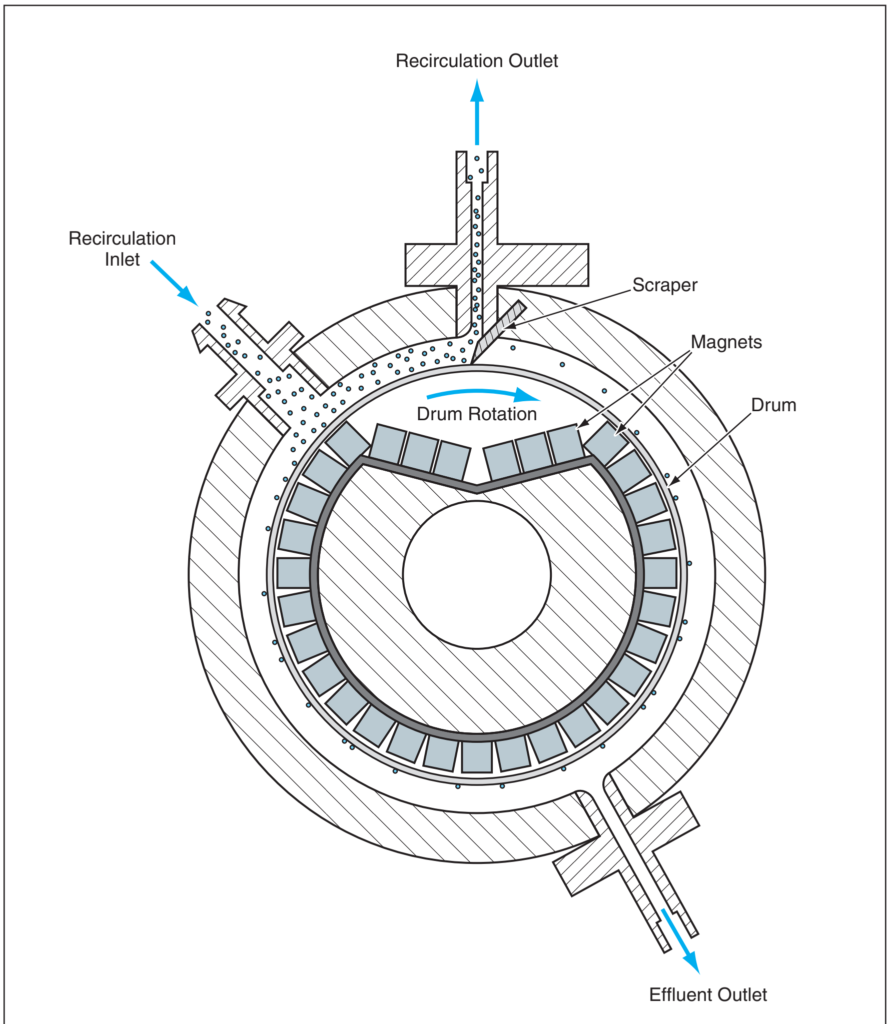

Figure 1. The **Magnetic Separator** rapidly separates magnetic sludge from wastewater.

As the drum rotates, it carries the attracted sludge to the recirculation outlet; the decrease in the magnetic field at this location releases the sludge from the drum, making it possible for the sludge to be flushed out by the recirculation-outlet flow. A poly(tetrafluoroethylene) scraper aids in removing any remnants of sludge that may still stick to the drum. An effluent outlet is positioned as far as possible from the recirculation ports in order to provide the longest possible separation path. The effluent flow amounts to about 20 percent of the inlet flow. The flows of sludge and effluent are controlled by use of a recirculation pump and an effluent pump, respectively.

The SRS (see Figure 2) includes two concentric tubes with relatively coarse filtering material (pipe cleaners) in the annular space between them. The wastewater is recirculated through the inner tube. Through an axial slot in the inner tube, a portion of the flow is diverted into the annular space between the tubes. This portion of the flow becomes filtered in the annular space and is drawn off as effluent through an axial slot in the outer tube on the side opposite that of the slot in the inner tube.

Eventually, any conventional filter becomes clogged and thereby loses hydraulic capacity and must be replaced. An ideal filter would have to continuously clean itself so as not to impede the flow of the filtrate. The SRS acts as such an ideal or nearly ideal filter because of the self-regenerating aspect of its operation:

- Initially, sludge builds up quickly in the pipe-cleaner flow field, where the sludge thus trapped serves as a fine filter medium for incoming sludge particles. As more sludge builds up toward the interior of the inner tube, it is ex-

posed to the fast recirculation flow, which washes away newly settled sludge. A dynamic equilibrium is quickly reached between the deposition and removal of sludge.
- Unlike what would happen in a conventional filter, the buildup of sludge in the pipe-cleaner flow field does not continue indefinitely until excessive clogging occurs. Instead, the SRS design utilizes the fact that sludge is a living organism that digests its own dead parts stagnating in the pipe-cleaner flow field. The digestion process continuously opens up new filter pores that make it possible for water to continue to flow. This process gives rise to a second dynamic equilibrium — between clogging and the generation of new flow paths in the pipe-cleaner flow field.

Only the first pipe cleaner is needed as a filter element; the other pipe cleaners are needed only for support of the tubes in their coaxial alignment. Prior to testing, it was expected that sludge would slowly migrate through the pipe-cleaner flow field and reach the effluent port, where it would reduce the quality of the filtrate. Instead, it was found that the sludge remained stationary at the first pipe cleaner and no migration was observed, even after two weeks of operation.

This work was done by Shivaun Archer, G. Duncan Hitchens, Harry Jabs, Jennifer Cross, Michelle Pilkinton, and Michael Taylor of Lynntech, Inc. for Johnson Space Center. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809. Refer to MSC-23293

Portable Unit for Metabolic Analysis

Respiratory signals can be temporally resolved within respiratory cycles.

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The Portable Unit for Metabolic Analysis (PUMA) is an instrument that measures several quantities indicative of human metabolic function. Specifically, this instrument makes time-resolved measurements of temperature, pressure, flow, and the partial pressures of oxygen and carbon dioxide in breath during both inhalation and exhalation.

Portable instruments for measuring these quantities have been commercially available, but the response times of those instruments are too long to enable temporal resolution of phenomena on the time scales of human respiration cycles. In contrast, the response time of the PUMA is significantly shorter than characteristic times of human respiration phenomena, making it possible to analyze varying metabolic parameters, not only on sequential breath cycles but also at successive phases of inhalation and exhalation within the same breath cycle.

In operation, the PUMA is positioned to sample breath near the subject's mouth. Commercial off-the-shelf sensors are used for three of the measurements: a miniature pressure transducer for pressure, a thermistor for temperature, and an ultrasonic sensor for flow. Sensors developed at Glenn Research Center are used for measuring the partial pressures of oxygen and carbon dioxide:

- The carbon dioxide sensor exploits the relatively strong absorption of infrared light by carbon dioxide. Light from an infrared source passes through the stream of inhaled or exhaled gas and is focused on an infrared-sensitive photodetector.
- The oxygen sensor exploits the effect of oxygen in quenching the fluorescence of ruthenium-doped organic molecules in a dye on the tip of an optical fiber. A blue laser diode is used to excite the fluorescence, and the optical fiber carries the fluorescent light to a photodiode, the temporal variation of the output of which bears a known relationship with the rate of quenching of fluorescence and, hence, with the partial pressure of oxygen.

The outputs of the sensors are digitized, preprocessed by a small onboard computer, and then sent wirelessly to a desktop computer, where the collected data are analyzed and displayed. In addition to the raw data on temperature, pressure, flow, and mole fractions of oxygen and carbon dioxide, the display can include volumetric oxygen consumption, volumetric carbon dioxide production, respiratory equivalent ratio, and volumetric flow rate of exhaled gas.

This work was done by Daniel L. Dietrich, Nancy D. Piltch, Mark E. Lewis, Jeffrey R. Juergens, Michael J. Lichter, Peter M. Struk, and Dale M. Diedrick of Glenn Research Center; Russell W. Valentine of Case Western Reserve University; and Richard D. Pettegrew of the National Center for Microgravity Research.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17945-1.