



⚙️ Vapor-Compression Heat Pumps for Operation Aboard Spacecraft

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Vapor-compression heat pumps (including both refrigerators and heat pumps) of a proposed type would be capable of operating in microgravity and would be safe to use in enclosed environments like those of spacecraft. The designs of these pumps would incorporate modifications of, and additions to, vapor-compression cycles of heat pumps now used in normal Earth gravitation, in order to ensure efficiency and reliability during all phases of operation, including startup, shutdown, nominal continuous operation, and peak

operation. Features of such a design might include any or all of the following:

- (1) Configuring the compressor, condenser, evaporator, valves, capillary tubes (if any), and controls to function in microgravitation;
- (2) Selection of a working fluid that satisfies thermodynamic requirements and is safe to use in a closed crew compartment;
- (3) Incorporation of a solenoid valve and/or a check valve to prevent influx of liquid to the compressor

upon startup (such influx could damage the compressor);

- (4) Use of a diode heat pipe between the cold volume and the evaporator to limit the influx of liquid to the compressor upon startup; and
- (5) Use of a heated block to vaporize any liquid that arrives at the compressor inlet.

This work was done by Warren Ruemmele, Eugene Ungar, and John Cornwell of Johnson Space Center. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809. MSC-23746

⚙️ Multistage Electrophoretic Separators

Separations can be performed in preparative quantities and can be automated.

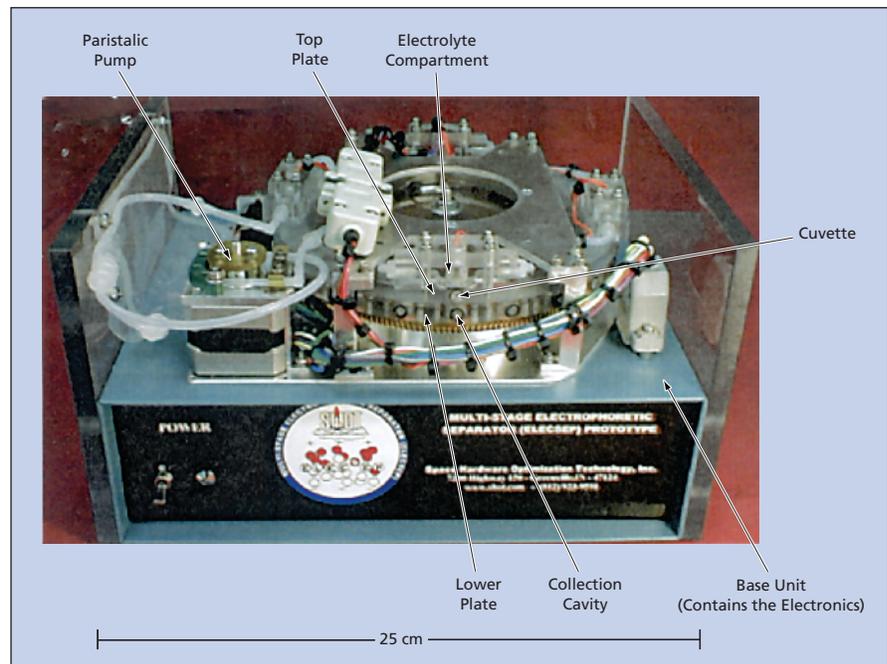
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A multistage electrophoresis apparatus has been invented for use in the separation of cells, protein molecules, and other particles and solutes in concentrated aqueous solutions and suspensions. The design exploits free electrophoresis but overcomes the deficiencies of prior free-electrophoretic separators by incorporating a combination of published advances in mathematical modeling of convection, sedimentation, electro-osmotic flow, and the sedimentation and aggregation of droplets. In comparison with other electrophoretic separators, these apparatuses are easier to use and are better suited to separation in relatively large quantities characterized in the art as preparative (in contradistinction to smaller quantities characterized in the art as analytical).

In a multistage electrophoretic separator according to the invention, an applied vertical steady electric field draws the electrically charged particles of interest from within a cuvette to within a collection cavity that has been moved into position of the cuvette. There are multiple collection cavities arranged in a circle; each is aligned with the cuvette for a

prescribed short time. The multistage, short-migration-path character of the invention solves, possibly for the first time, the fluid-instability problems associated with free electrophoresis.

The figure shows a prototype multistage electrophoretic separator that includes four sample stations and five collection stages per sample. At each sample station, an aqueous solution or



This **Multistage Electrophoretic Separator** contains four sample stations, of which one faces front in this view.

suspension containing charged species to be separated is loaded into a cuvette, which is machined into a top plate. The apparatus includes a lower plate, into which 20 collection cavities have been milled. Each cavity is filled with an electrophoresis buffer solution. For the collection of an electrophoretic fraction, the lower plate is rotated to move a designated collection cavity into alignment with the opening of the cuvette.

An electric field is then applied between a non-gassing electrode in the collection cavity and an electrolyte compartment, which is separated from the cuvette by a semipermeable mem-

brane. The electrolyte is refreshed by circulation by use of a peristaltic pump. In subsequent steps, the lower plate is rotated to collect other electrophoretic fractions. Later, the collected fractions are removed from the collection cavities through ports that have threaded plugs.

The base of the apparatus contains power supplies and a computer interface. The design includes provisions for monitoring and feedback control of cavity position, electric field, and temperature. The operation of the apparatus can easily be automated, as demonstrated by use of software that has already been written for this purpose.

This work was done by Nathan Thomas, John F. Doyle, Andy Kurk, John C. Vellinger, and Paul Todd of Space Hardware Optimization Technology, Inc., for Johnson Space Center.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to MSC-23208, volume and number of this NASA Tech Briefs issue, and the page number.

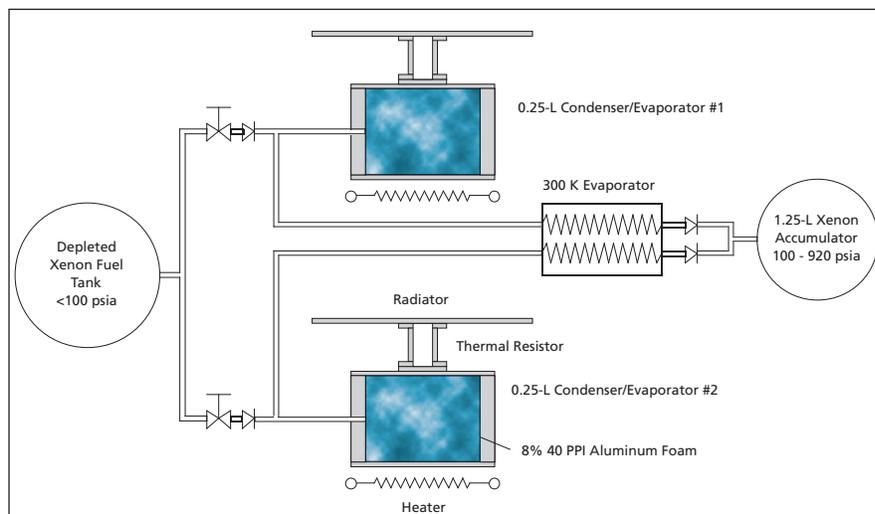
🔧 Recovering Residual Xenon Propellant for an Ion Propulsion System

Most of the otherwise unusable xenon is recovered.

NASA's Jet Propulsion Laboratory, Pasadena, California

Future nuclear-powered Ion-Propulsion-System-propelled spacecraft such as Jupiter Icy Moon Orbiter (JIMO) will carry more than 10,000 kg of xenon propellant. Typically, a small percentage of this propellant cannot be used towards the end of the mission because of the pressure drop requirements for maintaining flow. For large missions such as JIMO, this could easily translate to over 250 kg of unusable xenon.

A proposed system, the Xenon Recovery System (XRS), for recovering almost all of the xenon remaining in the tank, would include a cryopump in the form of a condenser/evaporator that would be alternatively cooled by a radiator, then heated electrically. When the pressure of the xenon in the tank falls below 0.7 MPa (100 psia), the previously isolated XRS will be brought online and the gas from the tank would enter the cryopump that is initially cooled to a temperature below saturation temperature of xenon. This causes xenon liquefaction and further cryopumping from the tank till the cryopump is full of liquid xenon. At this point, the cryopump is heated electrically by small heaters (70 to 80 W) to evaporate the liquid that is



A Proposed Xenon Recovery System promises to reduce waste of valuable cargo space on distant missions.

collected as high-pressure gas (<7 MPa; 1,000 psia) in an intermediate accumulator. Check valves between the tank and the XRS prevent the reverse flow of xenon during the heating cycle. The accumulator serves as the high-pressure source of xenon gas to the Xenon Feed System (XFS) downstream of the XRS. This cycle is repeated till almost all the

xenon is recovered. Currently, this system is being baselined for JIMO.

This work was done by Gani Ganapathi, P. Shakkottai, and Jiunn Jenq Wu of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40613