

are given. A 5.0 pitch diameter (PD) input gear to 7.50 PD (internal tooth) intermediate gear (0.667 reduction mesh), and a 7.50 PD (external tooth) intermediate gear to a 10.00 PD output gear (0.750 reduction mesh). Note that it is not required that the intermediate gears on the offset axis be of the same diameter. For this example, the resultant low-speed ratio is 2:1 (output speed = 0.500; product of stage one 0.667 reduction and stage two 0.750 stage reduction). The design is not restricted to the example pitch diameters, or output ratio. From the output gear, power is transmitted through a hollow drive shaft, which, in turn, drives a sprag during which time the main clutch is disengaged.

High-speed operation is direct-drive (1:1) through the main clutch. During

this mode of operation, the above gear train free-wheels the overrunning sprag. A slight reduction in input speed is required to overrun the sprag. The above gear train always spins.

The configuration was conceived to meet a rotorcraft drive design objective to provide a 50-percent reduction ratio. The configuration does so in two stages, or meshes, utilizing only three gears replacing multiple planet gears required in conventional planetary stages. A same-direction 50-percent reduction is not possible with a single-stage simple planetary gear configuration.

In addition, ratios other than 50 percent can be configured to meet specific design requirements. This configuration overcomes a technical design challenge of configuring a simple and ro-

bust two-speed/ variable-speed driveline transmission that is lightweight yet capable of transferring high power at high speed for next-generation rotary wing aircraft, which are forecast to require speed range variations on the order of 50 percent.

*This work was done by Mark A. Stevens of Glenn Research Center, and Robert F. Handschuh and David G. Lewicki of U.S. Army Research Laboratory, Vehicle Technology Directorate, (located at Glenn Research Center). Further information is contained in a TSP (see page 1).*

*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-18340-1.*

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## 🔧 Low-Dead-Volume Inlet for Vacuum Chamber

*John F. Kennedy Space Center, Florida*

Gas introduction from near-ambient pressures to high vacuum traditionally is accomplished either by multi-stage differential pumping that allows for very rapid response, or by a capillary method that allows for a simple, single-stage introduction, but which often has a delayed response. Another means to introduce the gas sample is to use the multi-stage design with only a single

stage. This is accomplished by using a very small conductance limit. The problem with this method is that a small conductance limit will amplify issues associated with dead-volume.

As a result, a high-vacuum gas inlet was developed with low dead-volume, allowing the use of a very low conductance limit interface. Gas flows through the ConFlat flange at a relatively high flow

rate at orders of magnitude greater than through the conductance limit. The small flow goes through a conductance limit that is a double-sided ConFlat.

*This work was done by Guy Naylor and C. Arkin of ASRC Aerospace Corporation for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Program Office at (321) 861-7158. KSC-13317*

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## 🔧 Simple Check Valves for Microfluidic Devices

**No additional materials or fabrication steps are necessary.**

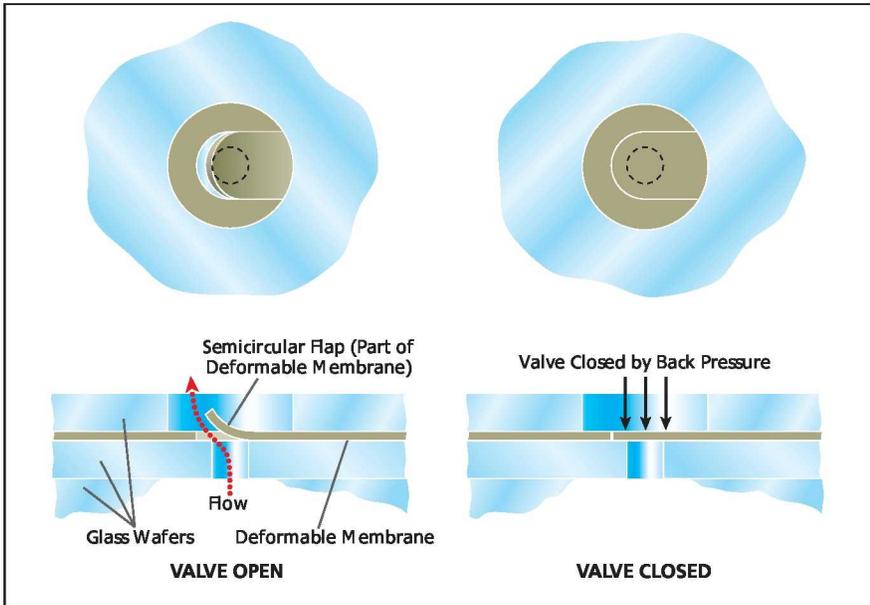
*NASA's Jet Propulsion Laboratory, Pasadena, California*

A simple design concept for check valves has been adopted for microfluidic devices that consist mostly of (1) deformable fluorocarbon polymer membranes sandwiched between (2) borosilicate float glass wafers into which channels, valve seats, and holes have been etched. The first microfluidic devices in which these check valves are intended to be used are micro-capillary electrophoresis (microCE) devices undergoing development for use on Mars in detecting compounds indicative of life. In this application, it will be necessary to store some liquid samples in reservoirs in the devices for subsequent laboratory analysis, and check valves are

needed to prevent cross-contamination of the samples. The simple check-valve design concept is also applicable to other microfluidic devices and to fluidic devices in general.

These check valves are simplified microscopic versions of conventional rubber-flap check valves that are parts of numerous industrial and consumer products. These check valves are fabricated, not as separate components, but as integral parts of microfluidic devices. A check valve according to this concept consists of suitably shaped portions of a deformable membrane and the two glass wafers between which the membrane is sandwiched (see figure). The

valve flap is formed by making an approximately semicircular cut in the membrane. The flap is centered over a hole in the lower glass wafer, through which hole the liquid in question is intended to flow upward into a wider hole, channel, or reservoir in the upper glass wafer. The radius of the cut exceeds the radius of the hole by an amount large enough to prevent settling of the flap into the hole. As in a conventional rubber-flap check valve, back pressure in the liquid pushes the flap against the valve seat (in this case, the valve seat is the adjacent surface of the lower glass wafer), thereby forming a seal that prevents backflow.



This **Microfluidic Check Valve** is a simplified version of a conventional rubber-flap check valve.

A typical sequence for fabricating a microfluidic device for the original intended microCE application includes the following steps:

1. Channels and valve seats are patterned in the two glass wafers between which

2. Holes are drilled through the wafers in predetermined locations for flowpaths.
3. The deformable membrane is fabricated.
4. Holes are punched in the membrane at locations matching those of holes, valve seats, and flow-channel orifices in the upper and lower glass plates. However, holes are not punched at locations where check valves are required.
5. At each check-valve location on the membrane, the check-valve flap is formed by use of an approximately semicircular punch. No membrane material is removed.

The ideal cut for forming a check-valve flap is an arc somewhat greater than a semicircle but less than a full circle. The resistance to flow through the check valve can be reduced by increasing the arc length of the punch. It is worth emphasizing that implementation of this concept entails nothing more than the use of additional punches for forming the flaps in the fabrication process.

*This work was done by Peter A. Willis, Harold F. Greer, and J. Anthony Smith of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45933*

## ⚙️ A Capillary-Based Static Phase Separator for Highly Variable Wetting Conditions

**Commercially viable two-phase flow/ liquid management field applications have been developed for microgravity.**

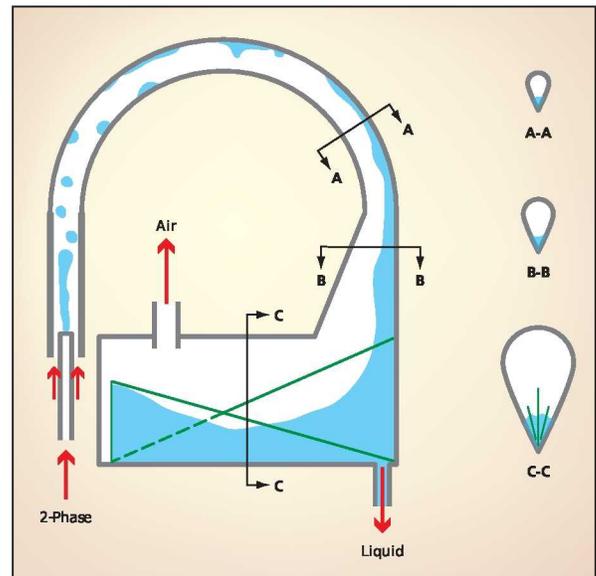
*Lyndon B. Johnson Space Center, Houston, Texas*

The invention, a static phase separator (SPS), uses airflow and capillary wetting characteristics to passively separate a two-phase (liquid and air) flow. The device accommodates highly variable liquid wetting characteristics. The resultant design allows for a range of wetting properties from about 0 to over 90° advancing contact angle, with frequent complete separation of liquid from gas observed when using appropriately scaled test conditions. Additionally, the design accommodates a range of air-to-liquid flow-rate ratios from only liquid flow to over 200:1 air-to-liquid flow rate.

The SPS uses a helix input section with an ice-cream-cone-shaped constant area cross section (see figure). The wedge portion of the cross section is on the outer edge of the helix, and collects the liquid via centripetal acceleration. The helix then passes into an increasing cross-sectional area vane region.

The liquid in the helix wedge is directed into the top of capillary wedges in the liquid containment section. The transition from diffuser to containment section includes a 90° change in capillary pumping direction, while maintaining inertial direction. This serves to impinge the liquid into the two off-center symmetrical vanes by the airflow.

Rather than the airflow serving to shear liquid away from the capillary vanes, the design allows for further penetration of the liquid into the vanes by the air shear. This is



A sketch of the **Static Phase Separator** illustrates the geometry.