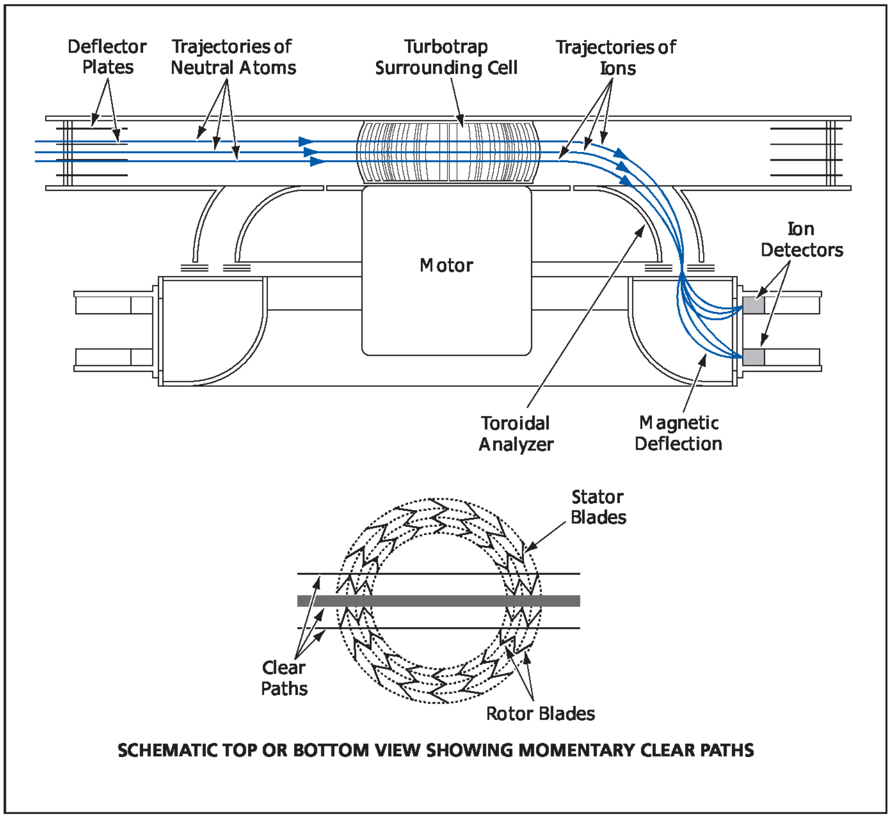
Turbomolecular Pumps for Holding Gases in Open Containers

Thermal gas atoms would be trapped; much faster atoms would pass through.

Goddard Space Flight Center, Greenbelt, Maryland

Proposed special-purpose turbomolecular pumps denoted turbotraps would be designed, along with mating open containers, to prevent the escape of relatively slowly (thermal) moving gas molecules from the containers while allowing atoms moving at much greater speeds to pass through. In the original intended applications, the containers would be electron-attachment cells, and the contained gases would be vapors of alkali metal atoms moving at thermal speeds that would be of the order of a fraction of 300 meters per second. These cells would be parts of apparatuses used to measure fluxes of neutral atoms incident at kinetic energies in the approximate range of 10 eV to 10 keV (corresponding to typical speeds of the order of 40,000 m/s and higher). The incident energetic neutral atoms would pass through the cells, wherein charge-exchange reactions with the alkali metal atoms would convert the neutral atoms to negative ions, which, in turn, could then be analyzed by use of conventional charged-particle optics.



Rotating and Stationary concentric rows of blades would momentarily open paths along which high-speed atoms could travel through the cell bounded by the blade circles.

The figure depicts selected aspects of a turbotrap as part of such an apparatus. The turbotrap would exploit the large difference between the speed range of the incident energetic neutral atoms and the thermal speed range of the alkali metal atoms in the cell. The turbotrap would consist primarily of two or more rotating concentric rows of blades interspersed with two or more concentric stationary rows of blades. The relative positions of the blades, the sizes of the gaps between them, and the speed of rotation would be chosen so as to periodically open up one or more straight path(s) through the cell during a time interval long enough to allow the incident energetic neutral atoms to pass through but short enough so that there would be no clear path through the cell for the slower thermal alkali metal atoms. Moreover, the blades would be shaped and oriented to pump most of the incident thermal atoms back into the cell.

The feasibility of several turbotrap designs has been tentatively demonstrated by means of computational simulations. For example, in the case of one design involving two rows of stationary vanes and two rows of blades on a circle of about 10-cm diameter, a gap of 0.5 cm between blades, 50-percent open area, and a rotational speed of 32,000 rpm, the simulation showed that >99 percent of alkali metal atoms entering the turbotrap would be returned to the cell. The rotational speed in this example is well within that attainable by exploiting recent developments in the technological disciplines of reaction wheels, gyroscopes, and conventional turbomolecular pumps.

This work was done by John W. Keller of Goddard Space Flight Center and John E. Lorenz of Litton Industries. Further information is contained in a TSP (see page 1). GSC-14402-1

Triaxial Swirl Injector Element for Liquid-Fueled Engines

The design is amenable to low-cost production.

Marshall Space Flight Center, Alabama

A triaxial injector is a single bi-propellant injection element located at the center of the injector body. The injector element consists of three nested, hydraulic swirl injectors. A small portion of the total fuel is injected through the central hydraulic injector, all of the oxidizer is injected through the middle concentric hydraulic swirl injector, and the balance of the fuel is injected through an outer concentric injection system. The configuration has been shown to provide good flame stabilization and the desired fuel-rich wall boundary condition.

The injector design is well suited for preburner applications. Preburner injectors operate at extreme oxygen-to-fuel mass ratios, either very rich or very lean. The goal of a preburner is to create a uniform drive gas for the turbomachinery, while carefully controlling the temperature so as not to stress or damage turbine blades. The triaxial injector concept permits the lean propellant to be sandwiched between two layers of the rich propellant, while the hydraulic atomization characteristics of the swirl injectors promote interpropellant mixing and, ultimately, good combustion efficiency. This innovation is suited to a wide range of liquid oxidizer and liquid fuels, including hydrogen, methane, and kerosene.

Prototype testing with the triaxial swirl injector demonstrated excellent injector and combustion chamber thermal compatibility and good combustion performance, both at levels far superior to a pintle injector. Initial testing with the prototype injector demonstrated over 96-percent combustion efficiency. The design showed excellent high-frequency combustion stability characteristics with oxygen and kerosene propellants. Unlike the more conventional pintle injector, there is not a large bluff body that must be cooled. The absence of a protruding center body enhances the thermal durability of the triaxial swirl injector.

The hydraulic atomization characteristics of the innovation allow the design to be rapidly scaled from small in-space applications [500–5,000 lbf (2.2–22.2 kN)] to large thrust engine applications [80,000 lbf (356 kN) and beyond]. The triaxial injector is also less sensitive to eccentricities, manufacturing tolerances, and gap width of many traditional coaxial and pintle injector designs.

The triaxial-injector injection orifice configuration provides for high injection stiffness. The low parts count and relatively large injector design features are amenable to low-cost production.

This work was done by Jeff Muss of Sierra Engineering Inc. for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32717-1.