# A novel angular motion vacuum feedthrough

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A novel angular motion feedthrough to vacuum has been designed and implemented at the Large Plasma Device at UCLA. The mechanism is easy and inexpensive to build. If linear motion capability is added, then one can arbitrarily and precisely position a probe within a specific volume in a vacuum chamber. © *2001 American Institute of Physics.* [DOI: 10.1063/1.1374588]

A novel angular motion feedthrough to vacuum has been designed and implemented at the Large Plasma Device (LAPD) laboratory at the University of California Los Angeles. At our lab we do plasma physics experiments in a large (1 m diameter by 10 m long) vacuum chamber. We routinely probe the internal volume with a variety of detectors in order get data on spatially varying properties of the plasma. Motion feedthroughs to vacuum are essential to our work as they would be to anyone needing to have access to the internal volume of their vacuum chamber.

Usually, angular motion vacuum feedthroughs require the use of a welded bellows. This presents several drawbacks: bellows are inherently expensive and expensive to incorporate in a design requiring delicate and sometimes sophisticated welding techniques. Bellows have a limited lifetime allowing a finite number of bending cycles before they fatigue and start to leak. If the bending is increased the limiting number of cycles decreases. In our lab we first tried a bellows approach to two-dimensional angular motion. We required some kind of yoke in order to guide the bending since precision and repeatability are required of the motion. We settled on a design where the bellows was thread through an opening in the center block of a universal joint. Unfortunately this design only allowed angular motion in orthogonal directions. Moving the mechanism in an arbitrary direction resulted in forcing the bellows to twist about its axis and suffer considerable stress.

Before describing the details of the feedthrough we note that the design relies on the technique of differential pumping of sliding elastomer seals. Therefore maintaining a base pressure below $1\times10^{-8}$ Torr may not be feasible. Our experience is with mechanically backed turbo-molecular pumps on a vacuum system whose base pressure is $7\times10^{-8}$. At this pressure, actuating the feedthrough has very little effect.

The basic concept of our angular motion feedthrough is best communicated visually using Fig. 1. Figure 1(a) is a cross section of the mechanism in its axially aligned state. In this state it is rotationally symmetric, and the cross section is along the symmetry axis. The essential parts are the bored out ball and the two component socket (the ring and the body). The ball is positioned and sealed with two supporting O-rings which make contact along two parallel nonequatorial circles. The geometry of contact should be clear because, as mentioned, the mechanism is rotationally symmetric in the state drawn. The two O-rings also enclose the intermediate vacuum chamber, which is differentially pumped through a pump out port [see Fig. 1(b)]. The socket is in two parts so the mechanism can be assembled. The socket O-ring [see Fig. 1(a)] is therefore necessary to maintain the integrity of the intermediate vacuum chamber. In Fig. 1(b) the mechanism is depicted in an off-axis state. Notice that with sufficiently compressed supporting O-rings there will be little change in the center position of the ball as it is rotated. This simple design provides unrestricted and repeatable angular motion.

When the angular degrees of freedom are combined with another degree of freedom provided by a linear motion feedthough [as in the differentially pumped version depicted in Fig. 1(b)], the end of an inserted shaft can be placed anywhere within a conical volume. The length of the cone is set by the limits of linear motion and the angle of the cone is set by the geometry of the ball neck and socket ring. The size of the bore in the ball determines the size of the ball neck. If the apparatus to be manipulated in the vacuum need not be removed, the bore needs only to be as big as the shaft diameter; this affords a large angular range of motion. On the other hand, it may be that apparatus must be periodically removed or changed while vacuum is maintained (with the help of an intermediate gate valve, not shown). If so, and if the transverse dimensions of the apparatus are larger than the shaft diameter, then the opening must be larger to allow it to pass through. This will reduce the angular range of motion.

The geometry of the socket ring is determined by the separation of the ball supporting O-rings. Here the design consideration is to anticipate stress on the ball. Consider the situation where the O-rings are very close, i.e., their positions of contact which subtend polar angles $a$ and $b$ [see Fig. 1(a)] are close to 90°. In this case a small axial force (like that due to atmospheric pressure) on the ball will result in a considerable displacement possibly inviting a breach of vacuum. On the other hand, if the angles $a$ and $b$ are far from 90°, then axial stresses will result in less axial displacement increasing the positioning reproducibility. However, the range of motion will be reduced. In the design presented the polar angles are $a=69°$ and $b=111°$. These angles are sufficient to stabilize the ball given the stresses imposed by our angular drive mechanism and atmospheric pressure. This

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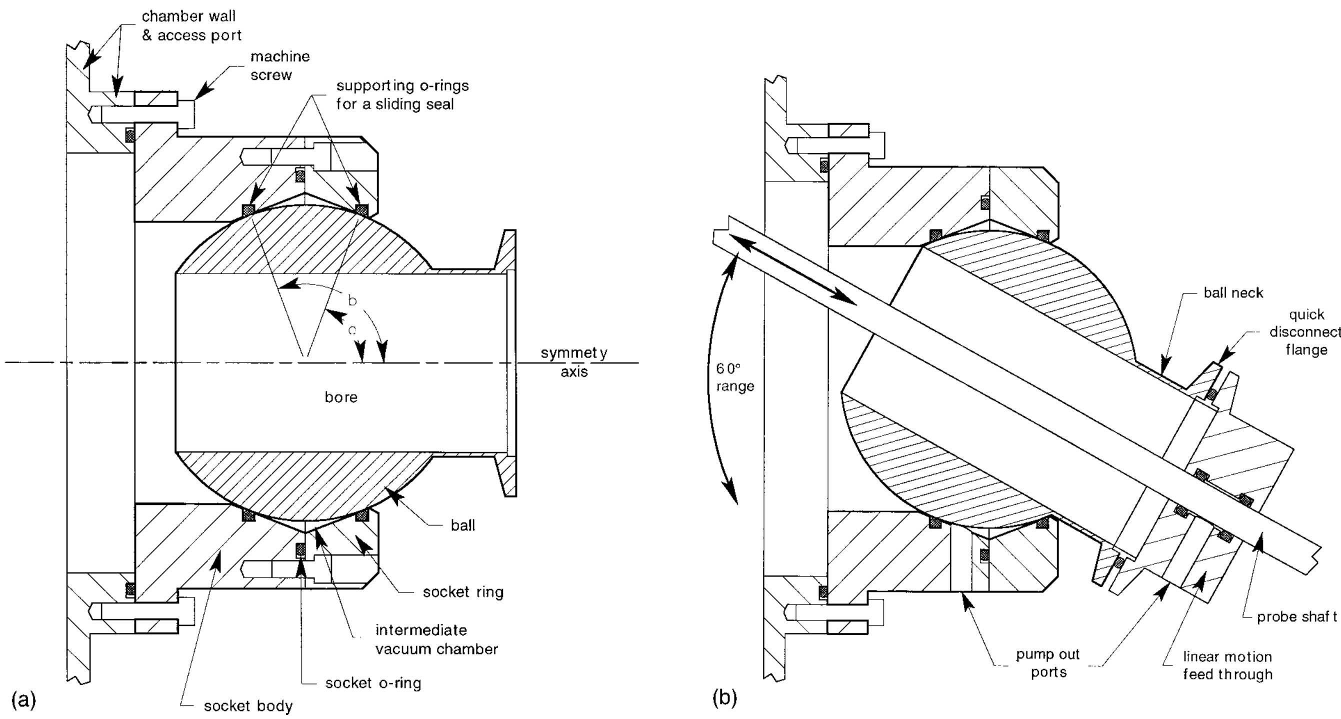


FIG. 1. Mechanical drawing of angular motion feedthrough. (a) The mechanism is in the axially aligned state showing the essential features of the design, i.e., the ball, the two component socket, the supporting O-rings for a sliding seal, and the differentially pumped intermediate vacuum chamber. (b) The mechanism is shown in an off-axis state. Additional design features are included: the linear motion vacuum feedthrough and the pump out ports for the differentially pumped chambers.

O-ring positioning in combination with a 1.97 in. bore in a 3.5 in. diameter ball allows for a design with a 60° range of angular motion.

Detailed mechanical drawings can be downloaded from AIP's archival web site.[1] However, if the reader prefers to design the mechanism, the following features of the present design could prove useful. The inner walls of the socket are designed for clearance and simplicity only. They are not intended to bear the ball under any circumstances as this might result in scratches on the sealing surface thus compromising the vacuum. The O-ring groove is oriented in a way so as to make remachining easy if the O-ring is too compressed for free motion of the ball. We use an intermediate gate valve which is attached to the ball via a ''quick disconnect flange.'' We chose to terminate the ball neck in a simple cylinder and weld on an off-the-shelf flange. The reader may decide to incorporate the features of a preferred flange into the design of the ball piece. Clearly this increases the difficulty in making the part. On the other hand, the concentricity and perpendicularity inaccuracies encountered with welding are avoided.

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[1] See EPAPS Document No. E-RSINAK-72-001107 for detailed mechanical drawings. This document may be retrieved via the EPAPS homepage (http://www.aip.org/pubservs/epaps.html) or from ftp.aip.org in the directory /epaps/. See the EPAPS homepage for more information.