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[6]A schematic circuit diagram of the motor controller (Slo-Syn Preset Indexer, model SP1800B-2) is available from the Superior Electric Company, Bristol, CT.
[7]In the Slo-Syn preset indexer, model SP1800B-2, completion of a step is actually indicated by a step function which is inverted and converted into a pulse using an SN7404 hex inverter. Other commercial motor controllers put out a stop pulse and the hex inverter can be eliminated. For this reason, no inverter is shown in Figs. 1 and 2.
[8]The general purpose FET analog gate (single pole–single throw switch) CAG-30 is available from Teledyne Crystalonics, 147 Sherman Ct., Cambridge, MA 02140.
[9]Details concerning edge-triggered J–K flip–flops are available in *Integrated Circuits Catalog for Design Engineers* (McGraw–Hill, New York, 1973).

A triaxial rotating vacuum seal

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A description is given of three concentric rotating vacuum seals employing reentrant geometry.

Rotating vacuum seals have many applications and the techniques for making such seals are well documented. In our laboratory we have recently built a device which requires three concentric rotating vacuum-tight seals. The seals are used for a rotating dilution refrigerator which is employed in studies of rotating superfluid He. Our design for these seals, although quite straightforward, seemed to warrant a short descriptive note. In our rotating dilution refrigerator the three seals are needed to (1) pump on a "pot" of ^{4}He, (2) pump on the "still" in the dilution refrigerator, and (3) provide a return line for recondensing ^{3}He–^{4}He mixture. The same set of seals could be used for a continuously operating ^{3}He refrigerator or any apparatus requiring multiple rotating seals.

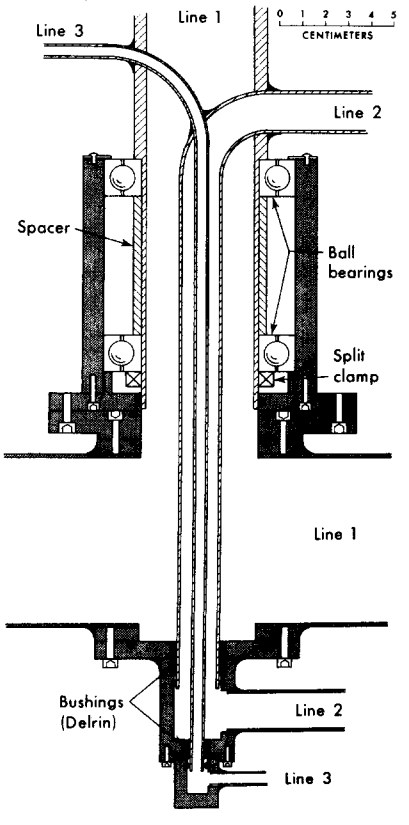

FIG. 1. Cross sectional sketch of the rotating vacuum seal. The rotating parts are shaded with dots and the stationary members are line shaded.

Figure 1 is a cross sectional drawing of these seals. Although topologically annoying, the seals are really quite straightforward to produce and assemble, providing that sufficient thought is given to the assembly sequence. This reentrant geometry could be expanded for more than three rotating seals.

The essential idea in each rotating seal is to keep the stationary and rotating tubes accurately concentric by means of a bearing. This is accomplished in the large diameter seal, line 1, by two precision ball bearings. In the two smaller seals Delrin bushings center the tubes. The actual rotating seals are made by Viton O-rings which are compressed a minimal amount to reduce friction. We employ O-rings with nominal cross sectional diameter of 1.6 mm which are compressed about 0.08 mm. A small amount of vacuum pump oil is applied on each O-ring. The O-ring only has to be an oil seal; the oil can make the actual vacuum seal. By compressing the O-rings such a small amount the seal requires a driving torque of only about 0.16 N·m. No leaks can be found in the rotating seals using a helium leak detector.

We have found these seals to be reliable and reasonably trouble free and to perform as expected.

We thank D. Dietrich for his expert technical assistance in the fabrication of these seals.

