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Technical Note

A reusable, low-profile, cryogenic wire seal

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ABSTRACT

We describe the design of a reusable indium wire seal which has a small profile and is leak tight to better than 1×10^{-10} std. cc/s from room temperature down to ≈50 mK. The pressure necessary to deform the indium wire o-ring is provided by a screw-cap mating to threads on the outside of the cylindrical volume to be sealed.

Indium wire seals are ubiquitous in low temperature apparatus such as ^{4}He, ^{3}He, and dilution refrigerator units as well as in room temperature applications where a very tight seal is necessary. While there are alternatives to indium seals [1], they are generally accepted as the most reliable low temperature seals. Conventional indium seals work by compressing an indium wire into a gasket under the pressure of several screws around the perimeter of a cylindrical volume. This set of screws, about 1 screw for every 15–20 mm of perimeter, must be tightened evenly to ensure a good seal and the threaded holes in the seal mount must extend into the interior of the vacuum space without penetrating it [2,3]. Larger thread sizes are preferable as there is less danger of stripping the threads or breaking the screws. However, these take up more space forcing the overall flange size and wall thickness to increase.

Here, as a space-saving alternative to conventional indium seals, we describe a low-profile indium seal which allows for comparatively thin walls. The seal has proven to be reusable, fast, and leak tight to $\leqslant 1 \times 10^{-10}$ std. cc/s at temperatures ranging from ≈0.05 K to ≈300 K [4]. Our design is shown in Fig. 1 in both a 3D view as well as in cross-section. It consists of three pieces referred to as the 'seal mount', 'cap' and 'screw-cap' which, in our case, were all made of brass. The seal mount consists of a machined brass tube which contains a shelf near the end to be sealed and 2.2 threads/mm (56 threads/in.) threading on the outside body. With an allen key hole machined into the center, the cap mates to the shelf of the seal mount. When seated, the cap extends beyond the top-most face of the seal mount but does not extend in the radial direction and is not flush with the outer diameter of the seal mount. A screw-cap with threads on its inner diameter which mate to the threads on the mount provides the pressure to compress the indium. The screw-cap has a hole in its face so that the cap can be held from turning with an allen key. Flats for an adjustable wrench were machined onto the screw-cap and the seal mount.

To apply the seal, a thin (0.76 mm diameter) wire of indium is wrapped around the cap so that the ends overlap for about 3–5 mm. Care must be taken to not allow excess indium to protrude from this annular region as it may interfere with the application of the screw-cap. In practice, the indium wire is dented slightly in the overlap region so it remains well positioned when placing the cap. The screw-cap, with vacuum grease applied on the surface contacting the cap to encourage slippage, is then screwed to the seal mount until contact is made. Two opposing adjustable wrenches are used to tighten this seal while an allen key, inserted into the cap, is used to prevent the cap from turning relative to the seal mount and consequently shearing the indium.

The seal is easily removed and, when disassembled as described below, results in an intact indium gasket on the cap. This is accomplished by venting the sealed space elsewhere, removing the screw-cap from the mount and using the allen key to carefully turn the cap through a slight angle. If the allen key hole is deep enough the cap can then be removed by applying a slight angular pressure to the allen key while pulling it away from the seal mount.

The above procedures result in an indium gasket which can be re-applied in the same way and remains leak tight even at low temperatures. This second seal is easier and faster to apply since there is less risk of the cap turning as the screw-cap is turned

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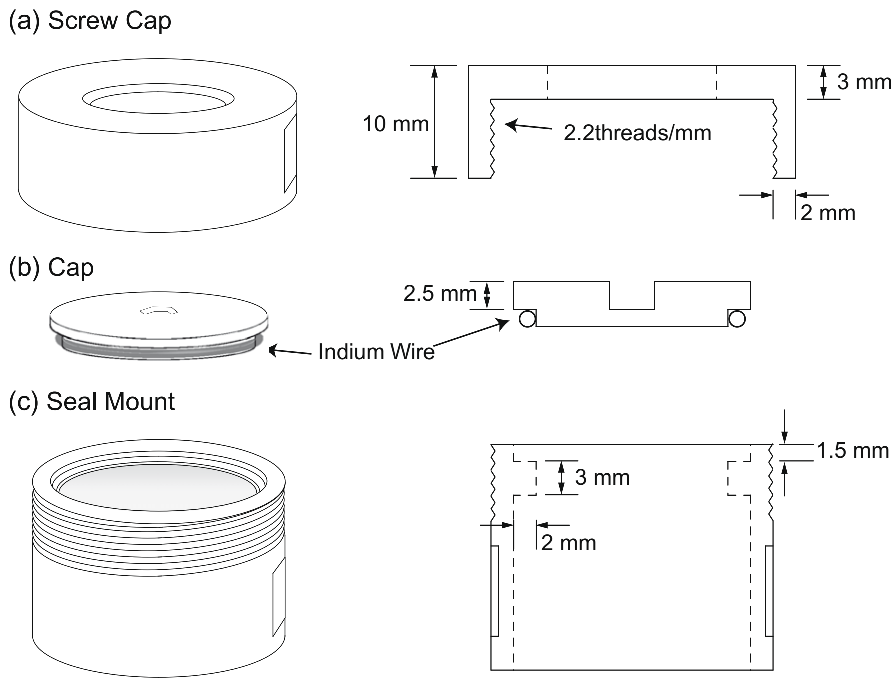

Fig. 1. Schematic of the seal discussed in the text.

and fewer turns of the wrench are necessary. In fact, in the interest of speed in our particular application, it has become our standard procedure to prepare a seal by making one vacuum tight seal and then reusing it for the actual experiment. We have tested the reliability of the original seal made with uncompressed indium wire several times and can report a ~90% success rate (out of ~10 trials). In every case where the original seal was leak tight the reused seal was also. We have not attempted to reuse a gasket more than twice after the original seal.

While the seal is effective at dilution refrigerator temperatures, we can suggest several potential improvements. First, the wall could be made thinner by removing the shelf for the indium wire in the seal mount and widening the area around which indium is wound on the cap. In order to ease the application of the indium wire, a short tail of wire may be accommodated by incorporating a small recessed area in the side of the seal mount. As an alternative to the somewhat awkward use of the allen key hole in the cap to ensure that the indium ring is not subjected to shear while the seal is tightened, the authors suggest a key arrangement on the cap and seal mount. Finally, as is done with conventional screw tightened indium seals, machining the screw-cap out of another material which thermally contracts more than the material of the cell mount would flatten the indium gasket further.

In summary, we recommend usage of this type of seal wherever there are volumetric restrictions and would favor it over those with a large number of very small (0–80 or 1–72) screws. In addition, it provides an alternative to silicone grease conical seals which require much more careful and tedious machining. It is not known whether the design described here seals with Pb/Sn wire (buss fuse wire) or whether the design is leak tight against superfluids.

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[4] The quoted low-temperature rate was determined by dipping the entire, leak-detector evacuated, seal into a liquid nitrogen bath, applying ^{4}He gas to the seal and failing to observe any signal on the leak detector as well as observing no indications of leakage when cooled to ~50 mK and filled with Helium gas.