# RESEARCH AND TECHNICAL NOTES

## Note on measuring loads at low temperatures (15K)

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In the course of building apparatus for high pressure experiments at low temperatures, we faced the problem of measuring loads (and hence pressures) in situ at low temperatures. A load ring manufactured by Engineering Specifics Assn., Inc. (Long Beach, CA) proved satisfactory down to 15 K.

The load ring is made of brass and is about 2.85 cm in diameter and 0.079 cm thick. Four strain gauges for low temperature applications are attached to the load ring, two on the inner wall and two on the outer wall, and connected in a bridge arrangement. The unit which we used has a range of 0 to 4.5 kg. The displacement at full load is less than $2.54 \times 10^{-3}$ cm. The high pressures are achieved by utilizing a diamond anvil formed between a diamond flat and a spherically tipped diamond indentor.[1]

The load ring was calibrated at room temperature, liquid nitrogen and liquid helium temperature (4.2 K). Fig. 1 shows the liquid helium temperature calibration as a plot of the load ring output (for a 10 V input) in millivolts versus load in grams. At all these temperatures the output is linear with load, and the slope is constant over long time intervals.

The sensitivity is 4.3 $\mu V/g^{-1}$ at room temperature and 3.9 $\mu V/g^{-1}$ at both liquid nitrogen and liquid helium temperature. There is some variation in the zero load value over very long time intervals (months), but this does not affect the ability to measure the loads during shorter times (days). Loads, or variation in loads, as small as 2 g can be measured easily.

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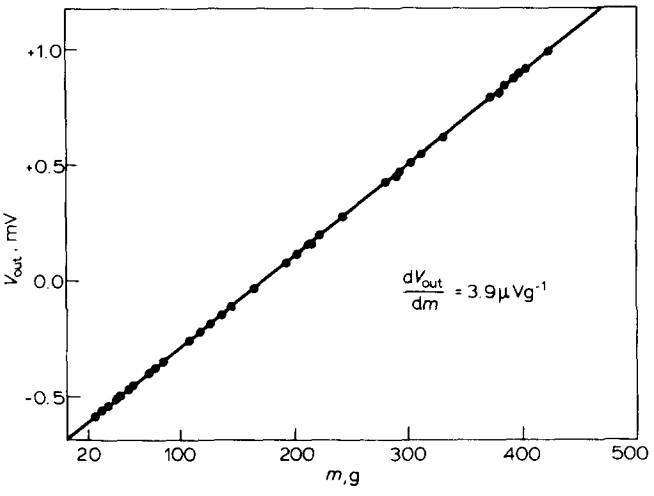


Fig. 1 Load ring calibration at liquid helium temperature

Smaller loads can probably be measured if the output signal is electrically amplified.

A total of ten cycles between room temperature and liquid helium temperature have been made with no deterioration of the load cell.

### Reference

1 **Ruoff, A.L., Chan, K.S.** High-pressure science and technology, ed. Timmerhaus K.D., Barber M.S., Proceedings of the Sixth AIRAPT International Conference on High-Pressure Science and Technology, Boulder, Colorado, USA, July 1977, Plenum, New York (1979) 779

## Rapid shutdown and restart of a millikelvin cryostat

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A copper adiabatic demagnetization refrigerator, precooled by a dilution refrigerator, has been used for several years in our laboratory to cool $He^3$ to the millidegree regime. We have found that it is possible to disassemble the cryostat for a simple repair, reassemble, and cool back down to low temperatures in only one day. Such a short repair time is not trivial in a large, low temperature apparatus. This note is intended to communicate a few simple ideas to other low temperature experimentalists who may find the techniques useful.

The essential piece of equipment for the procedure is a large, clear plastic tube, about 0.5 m diameter, 3 m long, and 0.1 mm thick, which surrounds the cryostat. The top end of the tube is sealed with tape to the woodwork which supports the top of the cryostat; the bottom end of the tube is left open. As with most cryostats of this size, access to the apparatus is gained by lowering the dewar while leaving the cryostat insert fixed (rather than pulling the insert up out of a stationary dewar). When the plastic tube is filled with helium gas, the dewar can be raised or lowered while full of liquid helium, without condensation of air or water into the dewar or onto the cryostat.

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### Changes outside the vacuum can

Using the tube, simple repairs (such as splicing a broken wire) on the outside of the isolation vacuum can are trivial. The tube is filled with gas, and the dewar is lowered just far

enough to expose the problem. Tools needed for the repair are poked through the tube, and the holes are taped shut when the repair is finished. Frost condensing on the outside of the tube makes it difficult to see clearly. An alternative technique, which has been used twice, is for the experimentalist to stand inside the tube, breathing through a hose.

The dewar is raised again as soon as possible after the repair. We find that if the process can be completed in less than a minute, the dilution refrigerator's mixing chamber and the demagnetization refrigerator's copper bundle never warm above a few tenths of a degree. Thus there is no need to remove the experimental $He^3$ or the dilution refrigerator mixture for such repairs. The system is back in operation immediately.

Helium boil off gas is not yet recovered at this laboratory, so the bottom of the tube has always been left open to the room. Sealing the tube bottom would seem to be a straightforward modification.

### Changes inside the vacuum can

Repairs inside the vacuum can require a more elaborate procedure. While the tube is being filled with helium gas, heat (about 1 W in total) is applied to the still, mixing chamber and copper cooling bundle (using resistors installed for that purpose), to begin boiling out the experimental $He^3$ and the dilution refrigerator mixture so that they can be stored in tanks for safety. When the tube is filled, the dewar is lowered away and covered. The 1° pot is vented to the room through a relief valve; mixture and $He^3$ continue to come out as the cryostat warms. Magnets and other accessories outside the vacuum can are removed immediately and set aside to warm up and dry. A heat gun or heater tape is used to hold the vacuum can slightly above room temperature. As soon as the $He^3$ and mixture are safe in their storage tanks, hydrogen exchange gas (used because of its high thermal conductivity) is admitted to the vacuum can, and the inner parts warm very rapidly. The vacuum can and radiation shield are removed as soon as the inner parts are warm enough so that moisture from the air will not condense on them; the repair process can then begin. This entire shutdown procedure only takes about an hour.

When repairs are complete, the cryostat is reassembled and checked for leaks and for wiring problems. Flushing of the experimental cell with $He^3$, which removes air from the cell more efficiently than simple pumping, is begun (and continues until the cell reaches $\cong$ 60 K). The tube is filled with helium gas. The magnet, with most of the cryostat's heat capacity, is precooled to 77 K by immersion in a bucket of liquid nitrogen for a few minutes. Hydrogen exchange gas is admitted to the vacuum space. When the nitrogen bucket is removed, the dewar, still partly full of liquid helium, is raised onto the cryostat until the boil off rate becomes excessive, indicating that the warm bottom of the cryostat is near the liquid surface. During the next few hours the dewar is slowly raised, while monitoring various thermometers and occasionally checking for leaks and electrical problems. When the parts inside the vacuum can have cooled to about 10 or 15 K, the hydrogen exchange gas is pumped out with a diffusion pump (flushing out any residual helium) and the vacuum space is sealed off. The dewar is then quickly raised the rest of the way, and more liquid helium is added if necessary. In this way the cryostat can be assembled and cooled to 4 K in about 6 h. Five to fifteen litres of liquid helium are consumed.

With these techniques the cryostat can be warmed, disassembled, reassembled, and recooled to liquid helium temperatures in an eight hour day. In our system, cooling the dilution refrigerator and copper cooling bundle from 10 K and condensing dilution mixture and experimental $He^3$ takes several additional hours because of the low steady-state cooling power of the 1° pot, which is determined by the flow impedance of the capillary which fills the pot continuously from the helium bath in the dewar. This will hopefully be modified soon. Another 36 h are required to adequately precool the magnetized copper refrigerant before demagnetization. Thus it is possible to return to 1 mK only 2 or 3 days after diagnosing a problem in the heart of the cryostat.

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# In situ cryogenic moiré strain analysis

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The moiré method of measuring mechanical displacements and strains has been extended previously to cryogenic environments.[1] In that case a replica of the active structural ruling was recorded photographically and processed subsequently on an optical bench to form the moiré fringes. The analysis was conducted both with and without fringe multiplication. An inconvenience of that approach was that conventional real-time fringe formation could not be viewed during actual loading. Subsequent effort has enabled the development of an in situ method by which live fringes within the cryogen can be viewed directly. This capability has decided advantages.

Moiré fringes occur due to the difference in pitch or orientation of two superposed transparent rulings or grids. By attaching one active ruling to a structural surface and analyzing it with an identical, aligned and transparent

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