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CONTINUOUSLY PUMPED ROTATING MILLIKELVIN CRYOSTAT

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We report the construction of a rotating nuclear demagnetization cryostat which can be continuously operated. The refrigerator employs a quadruple concentric rotating vacuum seal. The minimum ^{3}He temperature of this cryostat in the stationary state is 165 µK. In the rotating state there is a relatively large heat leak which depends both on the rotation rate and on the field in the main demagnetization magnet.

1. INTRODUCTION

The study of superfluid ^{3}He under rotation has yielded some of the most exciting results of the last decade (1). This field was pioneered with the construction of the ROTA 1 cryostat (2) at Helsinki, Finland. The dilution refrigerator of ROTA 1 operated in a one shot cryopumped mode. Soon afterwards an existing rotating cryostat at Cornell was modified for operation at millikelvin temperatures (3) which utilized continuous external pumping. These two machines were the only ones of their type until the completion of ROTA 2 in 1988 (4). ROTA 2 can be continuously operated using dual cryopumps. To permit research in this field at Berkeley a rotating millikelvin cryostat has been constructed. This paper gives preliminary results of the operation of this facility. A photograph of the cryostat is shown below in Figure 1.

2. AIR BEARING AND ROTATING VACUUM SEAL

The cryostat is suspended from a single circular steel plate of diameter 1 m. This plate is supported by three air pads pointing in the vertical direction which are 120° apart. Bolted to the bottom of the plate is a steel cylinder about 0.2 m high whose outer surface is positioned by three journal air pads, also 120° apart. These six pads form the air bearing which permits smooth rotation of the cryostat.

The four vacuum lines enter the rotating frame through a quadruple concentric rotating vacuum seal (5). This allows the pot and the dilution refrigerator (as well as the ^{4}He recovery from the bath) to operate continuously during rotation. This is a logical extension of the rotating dilution refrigerator built at Berkeley in 1974 (6).The electrical connections between the laboratory frame and the rotating cryostat are made through a 20 channel slip ring system mounted above the rotating vacuum seal.

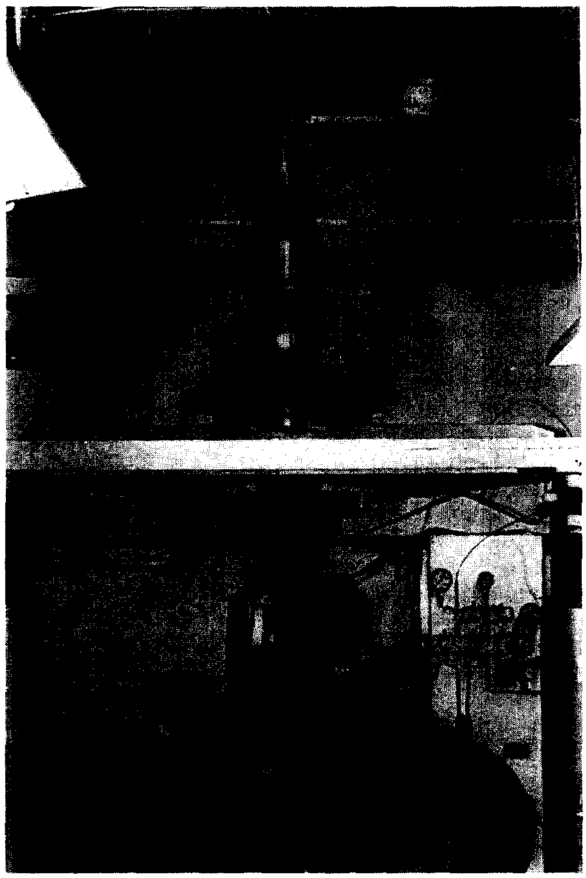

FIGURE 1. Rotating Nuclear Demagnetization Cryostat at Berkeley.

3. VIBRATION ISOLATION

The air bearing is supported on a triangular platform weighing 500 kg which rests on three air springs. Two of these are on top of Aluminum columns filled with sand and the third is bolted to the foundation wall of the building. The pumping system sits on an isolated concrete pad in the adjacent room. The interconnecting tubes first pass through bellows type vibration isolators (7) and then through a 5 tonne concrete block which is cemented to the foundation of the building. The tubes are then bolted to the foundation wall until they enter the rotating vacuum seal through a final set of bellows type isolators. The nuclear stage is connected to the mixing chamber by a 12 cm diameter Stycast 1266 cylinder of wall thickness 2mm which is 16 cm high. This is to increase the resonance frequency of vibration of the nuclear stage.

4. REFRIGERATION AND THERMOMETRY

The dilution refrigerator is a commercial OXFORD-400 model which cools to 6.5 mK with no load. The heat switch is made of aluminum diffusion welded to copper (8), with a compression joint at the bottom of the mixing chamber (9) and a bolted joint at the nuclear stage. This switch allows a precool to 9.5 mK to be carried out in 60 hours at 5.1 T average field. The nuclear stage is of the solid type (10) with 40 moles of copper in the high field region. This stage was annealed in vacuum at 850^0 C. The body of the heat exchanger is a container with a pattern of 2 mm diameter posts, electron discharge milled from a single piece of OFHC copper. This piece is silver plated and packed with silver powder to 50% solid density. To reduce the average distance between the ^{3}He and copper, 2 mm diameter holes are drilled into the sinter between the copper posts. This heat exchanger is electron beam welded to the top of the nuclear stage.

Thermometry is carried out by pulsed NMR on powdered Pt^{195} and utilizes the Greywall (11) temperature scale. The thermometers, as well as the heat switch and experiments have separate persistent superconducting magnets. A cylindrical superconducting shield surrounding each coil. The NMR electronics is completely in the rotating frame. These features simplify the operation of the thermometers during rotation.

5. OPERATION

In the stationary state the minimum ^{3}He temperature (at P=0) is 165 μK with a heat leak 0.7 nW after two weeks of operation. The time dependent heat leak starts at 36 nW and has almost disappeared after 10 days. The refrigeration of ^{3}He is reversible in the magnetic field down to about 0.3 mK.

The operation of the refrigerator under rotation is less satisfactory. At $\Omega = 0.5$ rad s^{-1} and with the main field up to 75 mT the heat leak is below 20 nW. For the same Ω, the heat leak grows rapidly with increasing field to 200 nW at 150 mT and 600 nW at 220 mT. Because of the magnitude of these heat leaks we have not yet addressed the heating due to the Earths field.

During these preliminary tests there is a large torque on the cryostat from the drive belt. We plan to eliminate this force and to improve the support structure for the nuclear stage before we next use the cryostat.

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