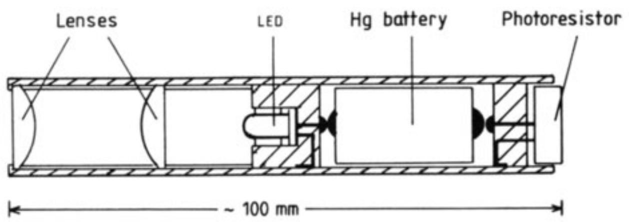

Figure 2. Centring device. A light-emitting diode (LED) serves as the point-source projector. By means of two lenses an image of the light-emitting crystal of the LED can be produced on the original. The LED is connected to a 5.4 V Hg battery via a photo resistor which automatically regulates the brightness of the LED according to the room illumination. Darkness or a hood put over the photoresistor turns off the LED instantly.

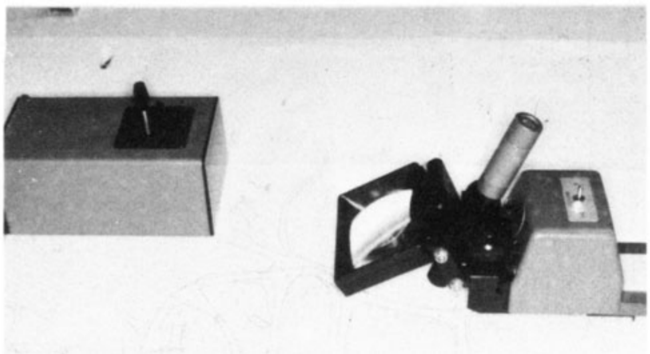

Figure 3. Picture of the control unit with the joy-stick (on the left), and the penholder with mounted centring device (on the right).

The principal advantage in using a computer combined with a plotter lies in the possibility of digitising parts of already existing maps or diagrams and having computer-edited supplements subsequently drawn on the original.

4. Centring device

A point source is projected on the original so that the precision of centring does not depend on the angle of vision. An appropriate light-spot projector is shown in figure 2. When power for the LED is supplied through a thin cable, the complete light-spot projector can be placed in a case no bigger than usual plotter pens.

If the distance between the penholder and the graph paper is constant at all places, better visibility of the light spot can be obtained by mounting the projector inclined so that the original is illuminated at an angle of about 75°. To improve precision a magnifying glass with a diameter of about 50 mm was also mounted on the penholder. This can only be done when a supporting wheel for the penholder is available. Because the size of the device was not very important to us, power for the LED could be provided by a Hg battery fixed to the penholder itself. The spot diameter of our projector is about 0.4 mm, but a larger spot can, of course, be obtained by defocusing. Figure 3 shows a photograph of the apparatus in use.

The large field of vision and the penholder control unit described allow point-by-point digitisation as well as continuous data registration when tracing curves.

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A simple continuous-flow helium cryostat for magnetic measurements

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Abstract. A cryostat working at 3.5–300 K is described. Samples up to 14 × 14 × 40 mm can be investigated, while the dimensions of the cryostat are very small (the width is 25 mm). Liquid He temperatures can be reached during 160 s, while only 0.16 l of liquid He is consumed.

1. Introduction

Continuous-flow helium cryostats are widely used in low-temperature physics experiments because of their simple

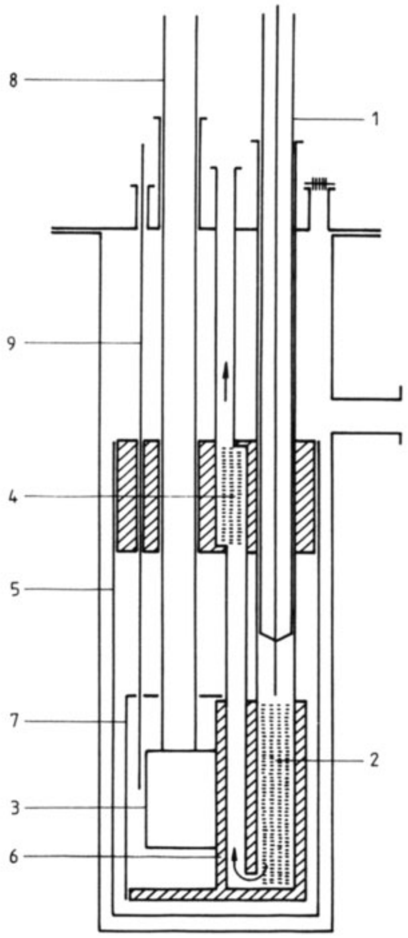

Figure 1. Schematic drawing of the continuous-flow cryostat. (1), Transfer tube; (2), main heat exchanger; (3), sample holder; (4), second heat exchanger; (5), radiation shield; (6), cold copper block; (7), shield; (8), waveguide; (9), rod.

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operation in a wide temperature range (Campbell and Herbert 1979). In this Institute a cryostat for magnetic measurements, especially suitable for EPR and FMR, has been developed. The conception was previously published by Půst (1979). We wish to present a more detailed description here.

2. Description of the cryostat

Figure 1 is a schematic drawing. Helium flows from a transfer tube (1), through the main heat exchanger (2), and cools the copper block with the sample holder (3). The outgoing gaseous helium cools, using the second heat exchanger (4), the gilded radiation shield (5) surrounding the experimental space. It substitutes the radiation shield cooled usually by liquid nitrogen. The cold copper block (6) is equipped with a set of threaded holes to keep a chosen sample holder in place. The space available under the withdrawable shield (7) exceeds 13 cm^3, which makes possible the use of samples up to $14 \times 14 \times 40$ mm. The rod (9) enables a rotation and/or shifts of the sample. Into this place can be introduced e.g. a waveguide (8) with a sample holder for magnetic resonance measurements. The cryostat has an oval shape with outer dimensions 25 and 50 mm.

The cryostat with all shields removed is shown in figure 2.

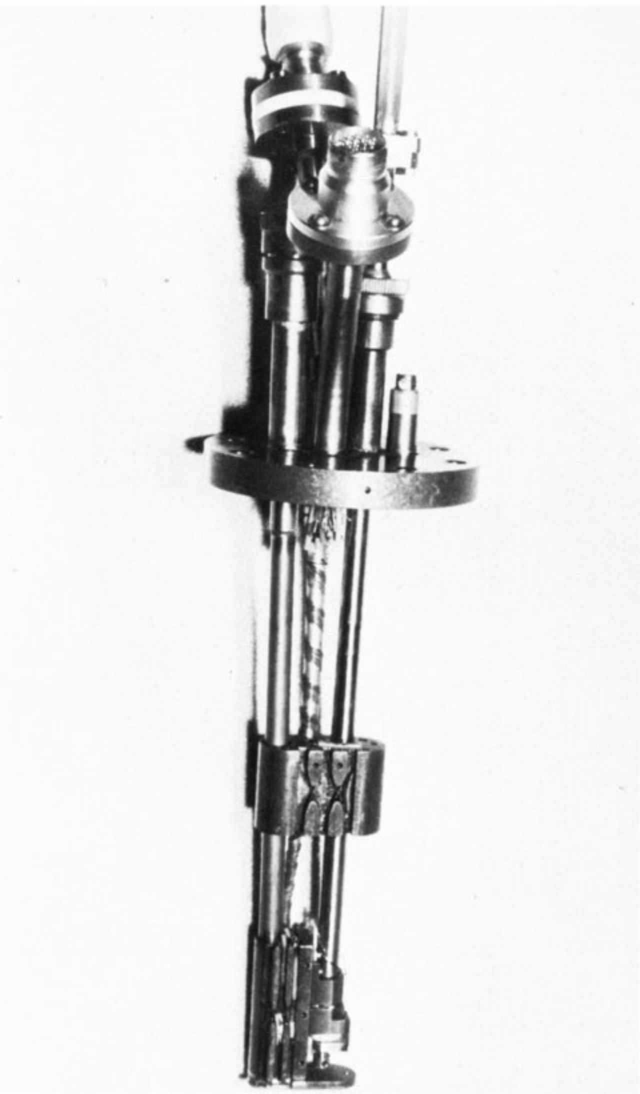

Figure 2. The cryostat with all shields removed (broad side).

The view on the narrower side of the cryostat prepared for measurement is shown in figure 3.

The cryostat was manufactured only from pure OFHC copper and nonmagnetic stainless steel thin-walled tubes in order to minimise the effect on the external magnetic field intensity. The magnetic susceptibility of all materials used was measured to verify their nonmagnetic behaviour.

In order to achieve small dimensions with effective use of the cooling medium (helium) porous heat exchangers were used (2, 4) made from copper nets (wire diameter 0.11 mm, 3 meshes/mm). The exceptionally good properties of this material have been pointed out in theoretical and experimental analyses performed by Půst (1977) and Málek *et al* (1977). The nets were sintered in vacuum into the copper blocks of the cryostat by the method of Steyert and Stone (1978). The main exchanger (2), which is in close thermal contact with the sample holder, has a free active surface of 180 cm^2 confined in a volume of only 1.85 cm^3; the second one has a surface of 185 cm^2 in a volume of 1.90 cm^3.

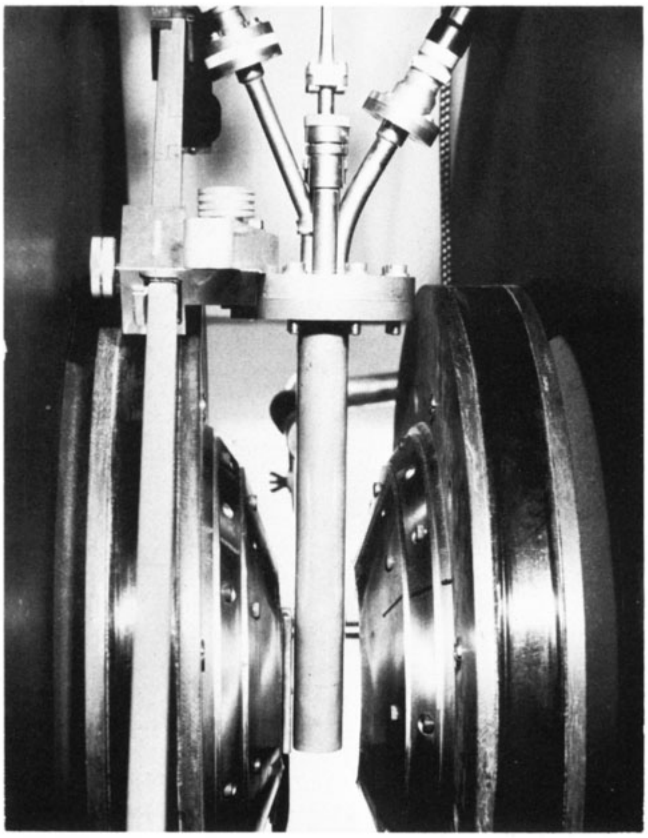

Figure 3. The view on the narrow side of the cryostat prepared for measurement.

During the measurement the helium is continuously pumped from the Dewar vessel through the cryostat. The flow can be set by the valve on the transfer tube and by adjusting the valve aperture before the pump. The electrical heater for fine temperature control is on the body of the main exchanger. The temperature is measured by a calibrated Lake Shore carbon–glass sensor.

3. The cryostat operation

The cryostat described enables quick and economical cooling of samples. Any temperature between 3.5 and 300 K can be reached and kept. Using the full helium flow a sample is cooled from room to helium temperature in only 160 s, while the helium consumption is only 20 g, which corresponds to 0.16 litres of liquid helium. The cooling rate of the cryostat is plotted in figure 4 together with the theoretical curves corresponding to the temperatures of the sample holder and the radiation shield, respectively. These curves were computed using the real masses of the lower copper block (155 g) and the higher copper block with the radiation shield (150 g). The computation was performed taking into account total helium enthalpy utilisation, i.e. high efficiency of the heat exchangers. All parasitic heat flows into the cryostat were neglected. Figure 4 shows the difference between the real performance of the cryostat and the ideal mathematical model to be small.

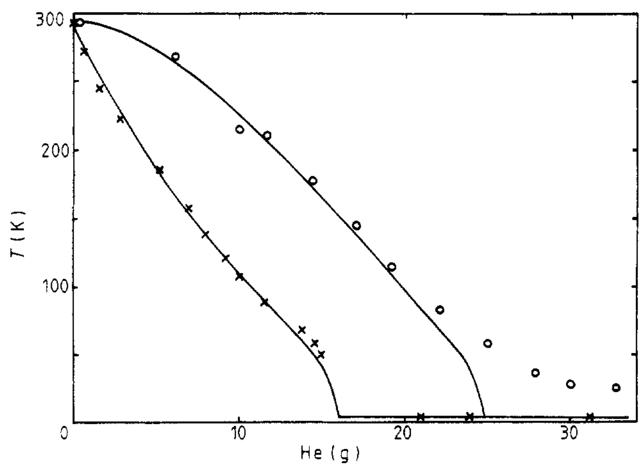

Figure 4. The experimentally measured temperatures of the lower copper block (×) and of the higher copper block with radiation shield (○) during the cooling of the cryostat as a function of the amount of consumed helium. The full curves correspond to the temperatures of these two parts of the cryostat computed according to the model of an ideal cryostat without losses and with full utilisation of the helium passing through exchangers.

In the steady-state regime the helium consumption near 3.5 K is about 0.11 g s^{-1} (3.5 litres of liquid helium per hour). At higher temperatures, the helium consumption falls down considerably. At temperatures above 100 K, the consumption is entirely negligible.

4. Conclusion

The continuous-flow helium cryostat described is very suitable for magnetic measurements owing to its small dimensions, quick and efficient operation and simple construction. The cryostat can be inserted in a 1 inch gap of a magnet. Any temperature between 3.5 and 300 K can be set.

Acknowledgments
The author wishes to acknowledge stimulating discussions and the aid of Dr Z Frait.

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