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Simple and inexpensive ^{3}He insert for an ac susceptometer

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Abstract. The design of a simple and inexpensive ^{3}He insert for the existing ac susceptometer is described. The system uses a home built mutual inductance bridge for the ac susceptibility measurements from 0·4 K to 300 K. Simple and inexpensive design with the top loading facility are the main features of this set up. The insert can also be used as a continuously ^{3}He operating refrigerator down to 0·5 K.

Keywords. ^{3}He insert; susceptometer.

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1. Introduction

One of the simplest ways to measure the magnetic susceptibility of the specimens is to use an ac susceptometer [1,2]. Many of the susceptometers discussed (from Anderson *et al* [3]; Deutz *et al* [4]) use expensive ratio transformers for simulating the mutual inductance. We have developed a mutual inductance bridge [5] which does not use a ratio transformer but has a sensisitivity of 10^{-7} emu/gm in a RMS field of 0·5 Oe. Recently, we have modified the circuit to operate the mutual inductance bridge from 10 Hz to 10 kHz. This mutual inductance bridge along with a PAR lock-in amplifier is fully automated via GPIB bus. We have also incorporated a small superconducting magnet (3 kOe) to measure the ac susceptibility in dc magnetic fields. In order to extend the temperature range of this susceptometer we have made a simple ^{3}He susceptometer which can be used in the single shot as well as in the continuous mode.

2. Design details

The ^{3}He insert is shown in figure 1. The ^{3}He insert consists of two glass tubes connected by a 40 mm long narrow capillary (0·3 mm diameter) tube. The outer glass tube has a length of 88 cm and a diameter of 15 mm where as the inner glass tube has a length of 91 cm and a diameter of 10 mm. The two glass tubes have separate brass couplings and finally joined at the bottom with the capillary. However, it is not essential to have two separate couplings. One can as well fuse the tubes together. Then one should have a glass nozzle for pumping the outer glass tube. In order to avoid such a glass nozzle or glass to metal coupling in the pumping line, we have used two separate brass couplings. Such a double wall chamber can be easily made in the glass blowing workshop. A small piece of dental floss is inserted in the capillary to provide the necessary impedance to the ^{3}He gas. The sample holder is made of gold plated OFHC

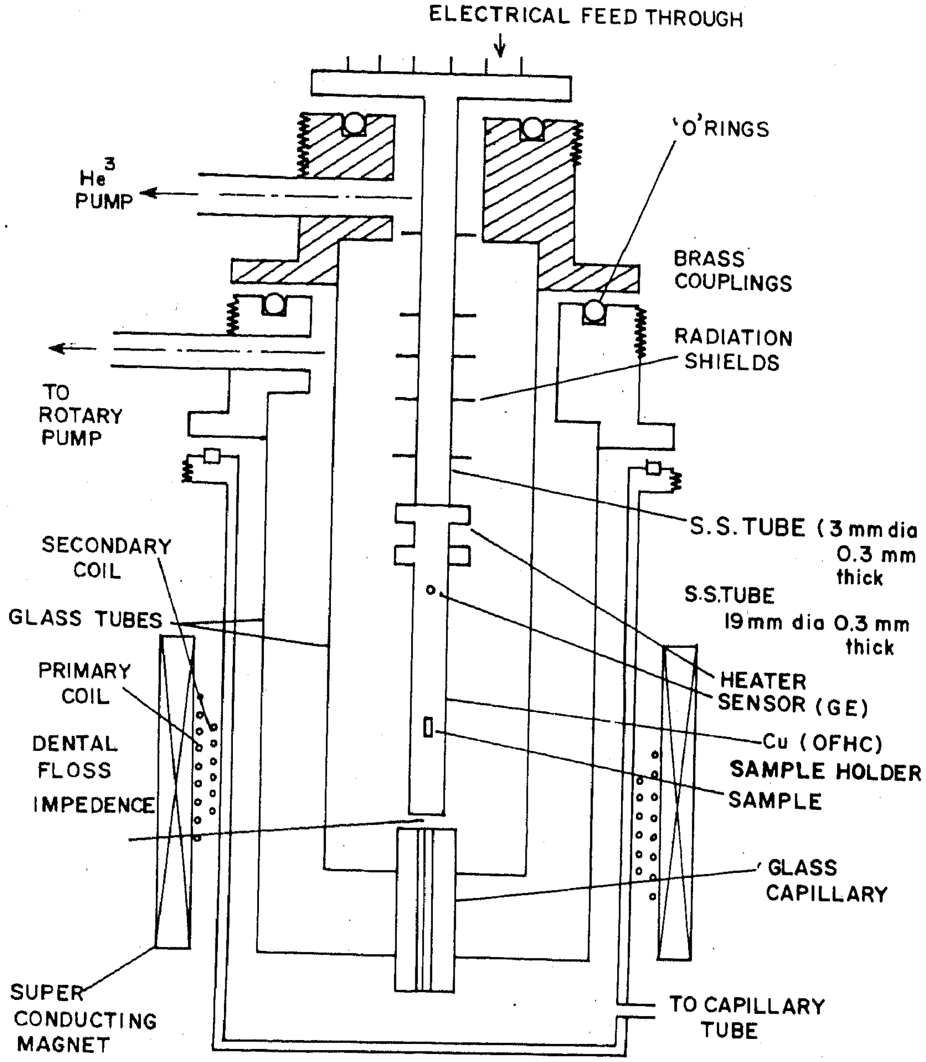

Figure 1. The ^{3}He insert made of two glass tubes connected by a glass capillary.

copper rod to which a calibrated Ge sensor (Lake Shore) is attached to measure the temperature from 0·4 K to 4·2 K. A different insert is used for the high temperature (4·2 K to 300 K) measurements. A small superconducting magnet (shown in the figure 1) is used for providing dc magnetic field of 3 kOe. The ^{3}He gas handling system is shown in figure 1. We have used a 10 litre fiber glass dewar (Precision Cryogenics, USA) as our main helium bath and roots pump in conjunction with the rotary pump (Alcatel, France) was used for pumping of this dewar. This ^{4}He bath cryostat is not shown here (for details see reference 9). All the vacuum connections have been checked with the mass spectrometer helium leak detector. The circulation pump is a hermetically sealed ^{3}He tight pump (from Alcatel, France). The external ^{3}He gas handling system (shown in figure 2) is connected to a double wall gas chamber and an outer stainless steel tube of diameter 19 mm and a length of 77 cm. The pick up coils (a primary and an astatic pair of secondary coils) are mounted outside this tube which will be at 1·5 K. The superconducting magnet is also mounted outside this stainless steel tube as shown in figure 1. The holder (made out of non-magnetic material) containing the pick up coils is rigidly attached to this magnet. This is essential to reduce the noise in the signal picked up by the secondary coil.

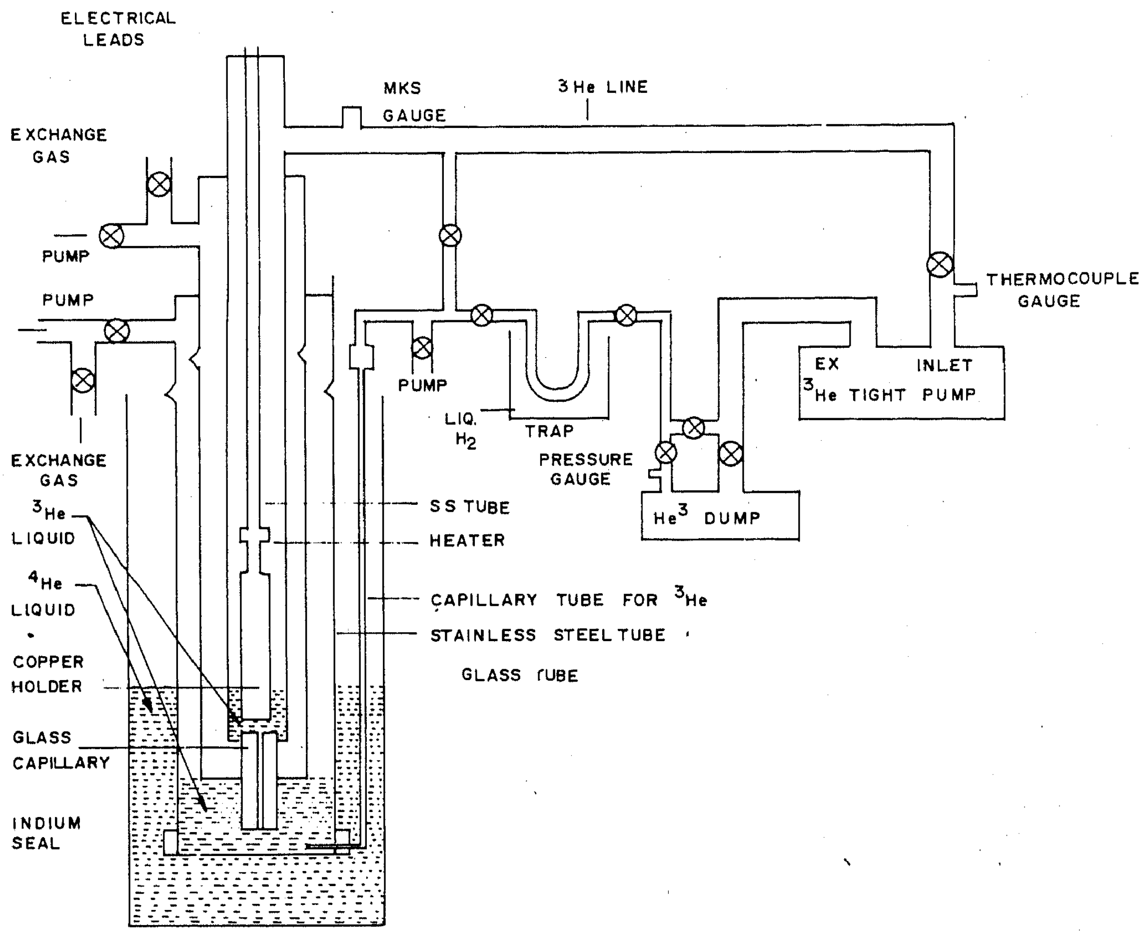

Figure 2. The ^{3}He gas handling assembly.

3. Results

Initially, the liquid ^{4}He is transferred to the main bath and this liquid is pumped down to 1·5 K. The gas from the ^{3}He dump is allowed to condense slowly in the stainless steel chamber at 1·5 K. Typically one uses 5 litres of ^{3}He gas at room temperature and after nearly all the gas is condensed, one starts the circulation with the hermetically sealed pump. The inter space between the two glass tubes is pumped with a normal two stage pump to vacuum better than 10^{-3} torr. The liquefied ^{3}He flows through a narrow capillary with an impedance from stainless steel chamber to the inner glass tube where the sample holder with the thermometer is located. With the continuously operating ^{3}He refrigerator, we have reached a temperature of 0·5 K whereas the single shot method yielded the lowest temperature of 0·4 K. Since we have used a high purity oxide free copper as a sample holder, there is no significant (< 1 mK) temperature gradient between the sample and the Ge thermometer which is substantiated by the measurement of superconducting transition temperature of high pure Cd(99·999%) wire.

We have used this set up to measure the superconducting transition temperature of 115 mg of cadmium wire. The ac susceptibility at 21 Hz in a rms field of 1 Oe is shown in figure 3. The value of superconducting transition temperature is in agreement with the literature values. The susceptibility of an A-15 Ti_3Pt (160 mg) compound is shown in figure 4. The superconducting transition temperature (0·6 K) is also in

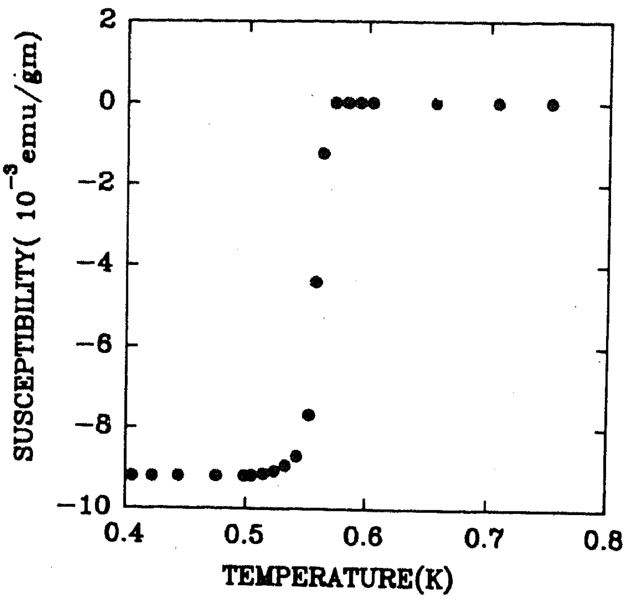

Figure 3. The temperature dependence of ac susceptibility of pure (99·999%) cadmium.

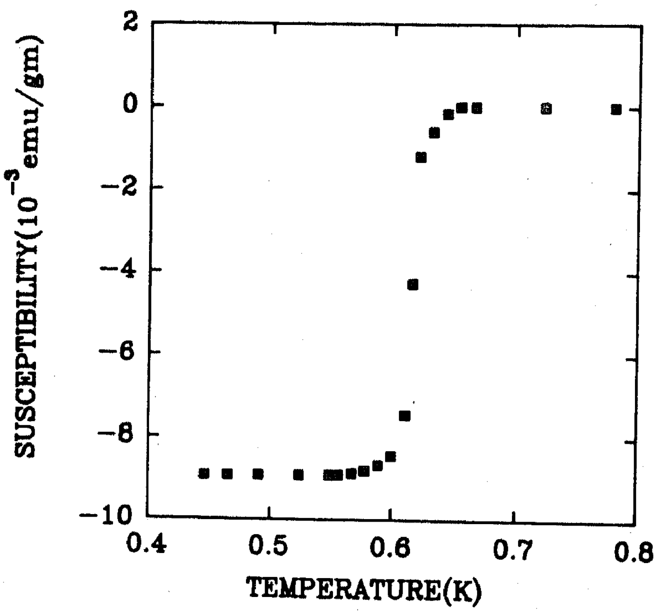

Figure 4. The temperature dependence of ac susceptibility of Ti_3Pt.

agreement with the previously published data. One can change the sample without warming the dewar (which is at 1·5 K) by pulling all the ^{3}He gas in the system back to the dump. This is possible by heating the sample holder above 20 K and at the same time keeping the pressure between the two glass tubes below 10^{-3} torr. After the recovery of all ^{3}He gas, ^{4}He gas is introduced in the sample chamber. Now the holder is removed when there is slight over pressure (above 760 torr) of ^{4}He gas in the sample chamber. The sample holder is dried and it is again inserted into the sample chamber with the new sample. This holder is now allowed to cool slowly to 1·5 K and then the ^{4}He is removed by pumping the system to high vacuum while the sample chamber is heated to temperatures above 20 K. After removing all the ^{4}He gas in the sample chamber, ^{3}He gas is introduced slowly and allowed to condense in the sample chamber. This top loading facility is possible because of the large volume of the superfluid ^{4}He (more than 3 litres) in our cryostat. However there is a risk of small contamination of ^{4}He with the pure ^{3}He gas by this method. This problem can be solved by pulling out the ^{3}He gas from the mixture at 0·7 K and storing it back to the dump at the end of the experiment. The remaining ^{4}He gas is discarded when the cryostat is warmed up to room temperature.

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