Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 520 (2004) 641–643
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
www.elsevier.com/locate/nima

Complete elimination of 1K Pot vibrations in dilution refrigerators

P. Gorla[a,b,c,*], C. Bucci[b], S. Pirro[c]

[a] *Laboratory of Nuclear and High Energy Physics, University of Zaragoza, Zaragoza 50009, Spain*
[b] *INFN - Laboratori Nazionali del Gran Sasso, Assergi (Aq) I-67100, Italy*
[c] *Dipartimento di Fisica dell'Università di Milano-Bicocca e Sezione di Milano dell'INFN, Milan I-20126, Italy*

Abstract

Cryogenic vibrations generated by continuously filled 1K Pots are a well known source of noise in all cryogenic experiments using dilution refrigerators. Starting from recent developments we realized a non invasive modification to the cryostat that completely eliminated vibrations, thermalizing the helium coming from the main bath at the pot temperature. We describe the new experimental setup and complete study of the phenomena.

PACS: the PACS codes can be found at the home page of NIMA (left column,under Contents Services):

Keywords: Superfluid helium; 1k pots; Vibration

1. Introduction

In recent years bolometric detectors have became very important in particle and low energy nuclear physics [1]. These kinds of detectors are very useful for searches for rare events (like neutrinoless double beta decay or WIMP searches for dark matter) and are for this reason very sensitive to the problem of background reduction. For the operation of bolometric detectors it is necessary to work at very low temperatures (tens of mK) that are only reached using dilution refrigerators. Cryogenic noise is a constant problem in all experiments using this kind of refrigerator; in particular coming from continuously filled 1K Pots (1KP). In recent years, many techniques were proposed to reduce the 1KP noise [2] without a clear comprehension of the origin of the noise. Recently a solution was proposed from Raccanelli et al. [3] modifying the refrigerator configuration.

2. Thermalization solution

The proposed solution is based on a very simple explanation of the phenomenon in terms of a phase transition between liquid and superfluid states of He. In fact in 1KP line of dilution refrigerators, liquid He coming from the cryostat's Main Bath (MB) at 4.2 K flows into the 1KP where it is pumped, reaching the temperature of about 1K (1.2 K in our cryostat). He in the pot is then quite a bit below the liquid-superfluid

*Corresponding author. Laboratory of Nuclear and High Energy Physics, University of Zaragoza, Zaragoza 50009, Spain. Tel.: +39-0862-437-281; fax: +39-0862-437-570.
E-mail address: paolo.gorla@ings.infn.it (P. Gorla).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2003.11.365

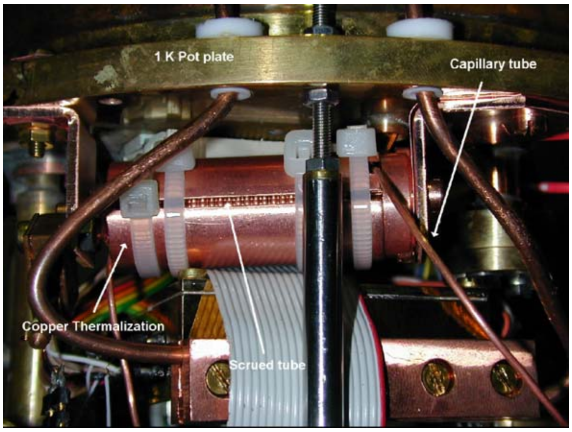

Fig. 1. The He thermalization.

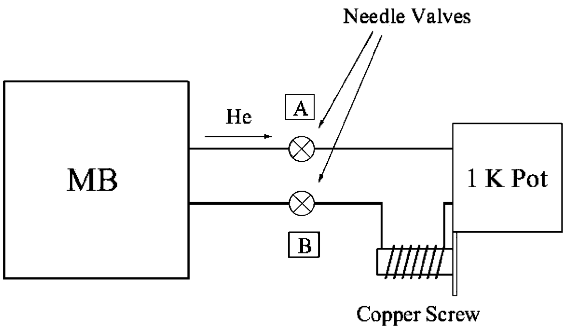

Fig. 2. Sketch of the MB-1KP connections. Each line has its own needle valves, controllable from outside, that allowed us to choose from time to time the configuration with (A close and B open) or without (A open, B close) the thermalization for a compared study of the behavior.

transition temperature (2.18 K) and is in the superfluid phase. When liquid He at 4.2 K drops into 1KP vessel, it generates an abrupt phase transition from superfluid to liquid in the region nearby producing turbulences. These turbulences generate vibrations in the pot that in our cryostat has a peak at about 11 KHz. To prevent this problem, a modification of the cryostat was proposed by thermalizing the He coming from MB at the pot's temperature before flowing into the pot, so that no phase transition occurs and no turbulence is generated. In this work we propose a non invasive technique by modifying the cryostat to simply introduce a capillary tube in the line between the MB and the 1KP that is thermalized on a copper screw at the 1KP temperature (Fig. 1). Fig. 2 is a sketch of our apparatus: the MB is connected to the 1KP by means of two tubes, each with it's own needle valve. We introduced in line B a capillary tube (about 1 m in length and 200 μm diameter) that is thermalized through a copper screw fixed to the 1KP at 1.2 K. In this way it was possible, by opening alternatively line A and line B, to test the behavior of the system in the two configurations.

3. Investigation

The study was performed in two steps: first we simply tested the Raccanelli [2] solution by means of piezoelectric detectors observing a great suppression in the vibration using the line-B open configuration. After the first confirmation we developed the study making a complete frequency spectrum of the vibrations of the 1KP with the same piezoelectric sensor and a second spectrum with an identical sensor fixed to the detectors holder. In Fig. 3 the spectrum acquired on the pot plate is presented with the direct valve open and the one on the thermalization line closed (light grey) and in the inverse situation (dark grey); it is evident the characteristic frequency of vibration of

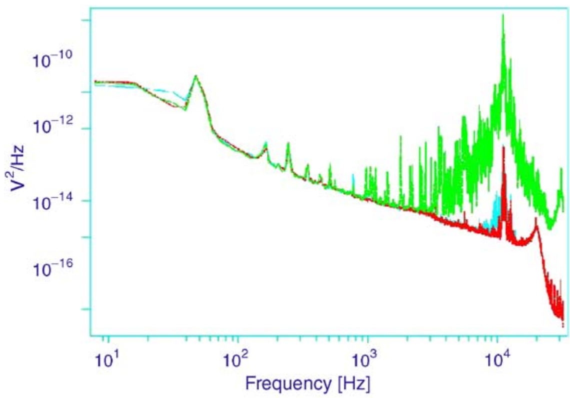

Fig. 3. Frequency spectrum on the pot plate with the direct valve open and the one on the thermalization close (light grey) and in the inverse situation (dark grey). (The color coding in the online version is: light-gray refers to green; dark-gray refers to red.)

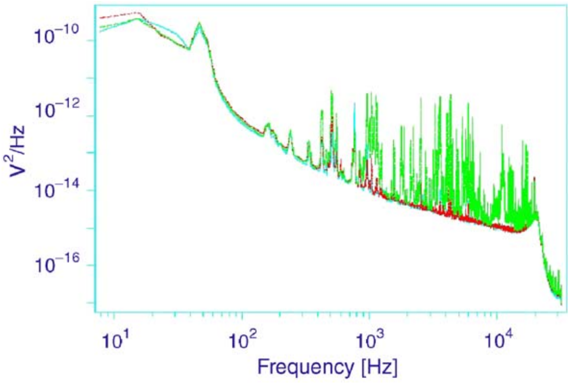

Fig. 4. Frequency spectrum on the detectors holder with the direct valve open and the one on the thermalization close (light grey) and in the inverse situation (dark grey). (The color coding in the online version is: light-gray refers to green; dark-gray refers to red.)

our pot, with a peak around 11 KHz. In Fig. 4 the same measurement is made on the detector holder. On the detector holder the frequencies are more distributed as an effect of the different vibrational modes of the parts of the structure. In both spectra the big electric peak at 50 Hz is evident and some of the odd harmonics (like 150 Hz): all of this, as expected, has no reduction by changing from one He channel to the other.

A further step in comprehension of the phenomena was achieved by measuring the temperatures of the He at different points. The setup was prepared by fixing calibrated thermometers (Lake Shore commercial type) on the He 1KP-thermalization line, and reading it with a dedicated monitor. One was fixed before the thermalization and the other immediately after; other thermometers where fixed on the 1KP and on the inner vacuum chamber (IVC) plate, that is at temperature of the MB. The system was then run with the needle valve on the direct connection always closed. The temperatures of MB and 1KP, if the cryostat operating characteristics are stable, don't vary as a consequence of our activities (opening and closing needle valve B, etc.) their typical values are 4.2 K for the MB (temperature of liquid He) and 1.2 K for the pot. At the beginning, valve B was closed; the temperature before the thermalization was of 3.1 K while after the thermalization was of 1.3 K. This is easily understood because they are connected respectively to MB (the length of the tube before the valve is about 40 cm) and 1KP (very nearby, only a few cm) and the thermalization is connected strongly to 1.2 K. When the B valve is open, the temperature before B goes to 4.2 K (due to the big flux coming from 1KP) and the one after to 1.5 K. So in a typical operating situation the incoming He temperature is quite below the liquid-superfluid transition T (about 2.18 K). All the temperatures correctly fit with our interpretation.

4. Conclusions and prospectives

The setup described in the earlier paragraphs, although a very simple modification of the cryostat, is very effective in reducing 1KP noise. Recent measurements show an improvement in the detector's baseline stability that certainly improves the resolution.

As a final consideration, we propose a possible application. Continuously filled 1K pots are used specifically for long time experimental runs, and for this reason it is necessary to balance the incoming He flux with the outgoing pumped He, maintaining in some way a stable level of He inside the pot while not altering the cryogenic setup. Since the impedance of the copper capillary is almost negligible for liquid He, the incoming flux is partially regulated by closing the needle valve. The temperature and the thermometer are very sensitive to this change, which allowed us to use it as a flux-meter. This technique proved to be very reproducible and has the advantage that, as soon as the pot is balanced, the thermometer can easily be disconnected form the outside preventing electric disturbance of the cryostat.

References

[1] C. Arnaboldi, et al., Nucl. Instr. and Meth. A 518 (2004) 775.
[2] S. Pirro, et al., Nucl. Instr. and Meth. A 444 (2000) 331.
[3] A. Raccanelli, et al., LTD 9, AIP Proc. 605 (2002) 391; A. Raccanelli, et al., Cryogenics 41 (2001) 763.