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Capacitive level meter for liquid rare gases

R. Sawada [a,*], J. Kikuchi [a], E. Shibamura [b], M. Yamashita [a], T. Yoshimura [a]

[a] *Advanced Research Institute for Science and Engineering, Waseda University, 17 Kikui-cho, Shinjuku-ku, Tokyo 162-0044, Japan*
[b] *College of Health Science, Saitama Prefectural University, 820 Sannomiya, Koshigaya-shi, Saitama 343-8540, Japan*

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Abstract

An international project to search $\mu \rightarrow e\gamma$ decay includes the use of a liquid xenon gamma ray detector. So, a liquid level meter working at a low temperature with low outgassing is needed and the prototype is constructed. The meter shows the liquid level by measuring the capacitance between electrodes with small intervals immersed in the liquid. The operation was successful with the estimated precision of 1 mm in RMS or better.

Keywords: Level meter; Liquid xenon; Capacitance

Liquid xenon has been used in scintillation calorimeters because of its fast response, large atomic number and high density. We will use a liquid xenon calorimeter in the international project to search $\mu \rightarrow e\gamma$ [1]. It will use a large amount of pure liquid xenon as the scintillation media, where the level of the liquid should be precisely controlled.

We have constructed a liquid level meter that works at a low temperature of 165 K at a pressure of 3 atm and that does not contaminate liquid xenon. The meter is a multi-parallel-plate capacitor. The meter consists of 9 G-10 plates set with Teflon spacers with 8 gaps of 1 mm. This approach aims to decrease errors in level measurement by increasing the capacitance signal. Each G-10 plate is covered with thin copper. The copper electrodes are gilded and are 20 cm high and 6 cm wide as shown in Fig. 1. The plates are connected so that they work as the anode and as the cathode alternately.

At first, the meter was tested in liquid nitrogen, because the liquid nitrogen is inexpensive and it is easy to directly measure the level with a ruler in the open air. As shown in Fig. 2 the capacitance increased linearly with the liquid level from 100 to 200 mm, where the capacitance is the measured capacitance minus that of lead wires and the stray capacitance. The sum of the capacitance of the lead wires and the stray capacitance was 500 pF. The root mean square deviation from the line fitted to the data for the level from 100 to 200 mm is 1.7 pF, which gives the precision for the level of 1 mm. The precision might be limited by the reading of the scale of about 1 mm. The actual error might be better than 1 mm. The measured capacitance of the meter was 853 pF in the air, and 1208 pF in liquid nitrogen, which are in good agreement with the calculated capacitance of 850 pF in the air and 1236 pF in liquid nitrogen of which the dielectric constant is 1.454.

Next, the meter was tested in liquid xenon with the chamber as shown in Fig. 3. The meter was fixed in the cylindrical chamber. To liquefy xenon, ethyl alcohol cooled by liquid nitrogen was used as a coolant. At 0 min, liquefaction was started. Fig. 4 shows that level reached to the bottom of electrodes at 75 min, and approached to the top at 170 min. The maximum capacitance of 1575 pF is fairly consistent with the calculated capacitance of 1670 pF in liquid xenon of which the dielectric constant is 1.96 [2]. The discrepancy between the measured capacitance and the calculated one is not fully understood. One cause might be an error in the dielectric constant. However, it is clear that the capacitance of 853 pF corresponds to a liquid level of 0 mm and 1575 pF to 200 mm in our measurements. The precision of the level should be better in liquid xenon than in liquid nitrogen since the dielectric constant in

* Corresponding author. Present Address: International Center for Elementary Particle Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Fax.: +81-03-3814-8806.
E-mail address: sawada@icepp.s.u-tokyo.ac.jp (R. Sawada).

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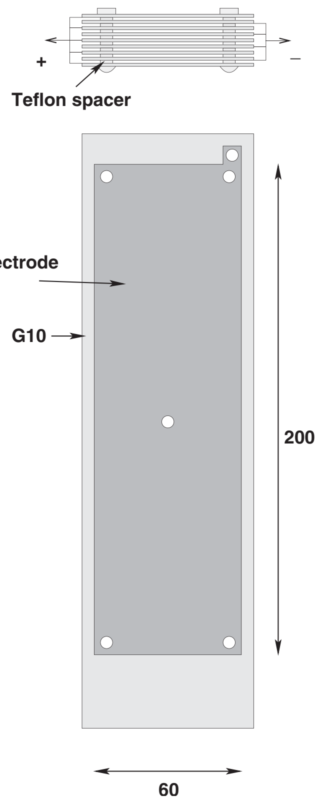

Fig. 1. Construction of the level meter. Copper electrodes are pasted on both sides of a G-10 plate of 1 mm in thickness. Plates are connected so that they work as the anode and as the cathode in turn.

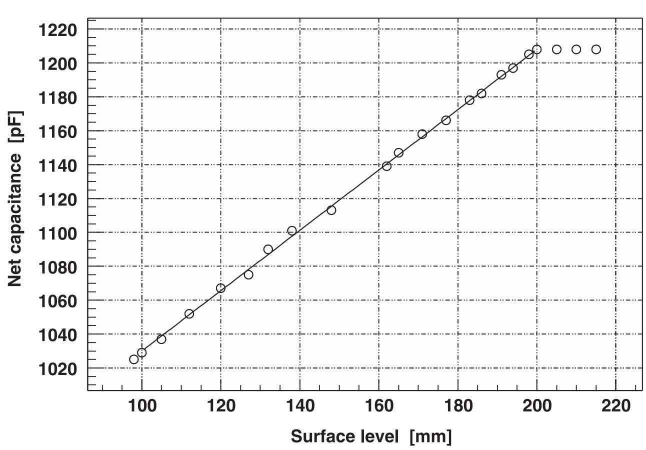

Fig. 2. Capacitance of the level meter in liquid nitrogen. The net capacitance does not include that of lead wires or that of the stray. Liquid level was measured with a ruler.

liquid xenon is larger. After maintaining the level for 40 min, liquid xenon was removed. Fig. 4 shows the temporal variation of the capacitance. The meter successfully measured the level. The reproducible results were obtained in the test made after the meter took the temperature of the room.

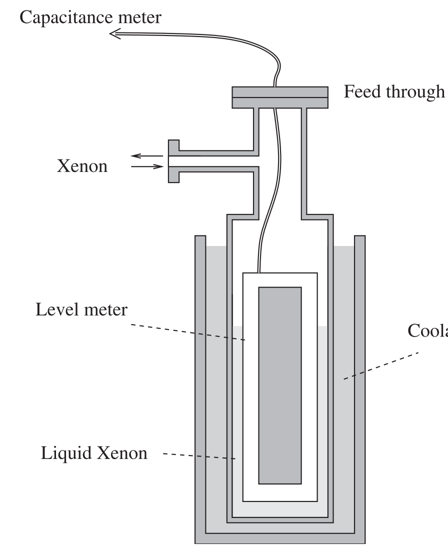

Fig. 3. A cylindrical chamber for liquid xenon. Ethyl alcohol cooled by liquid nitrogen was used as a coolant.

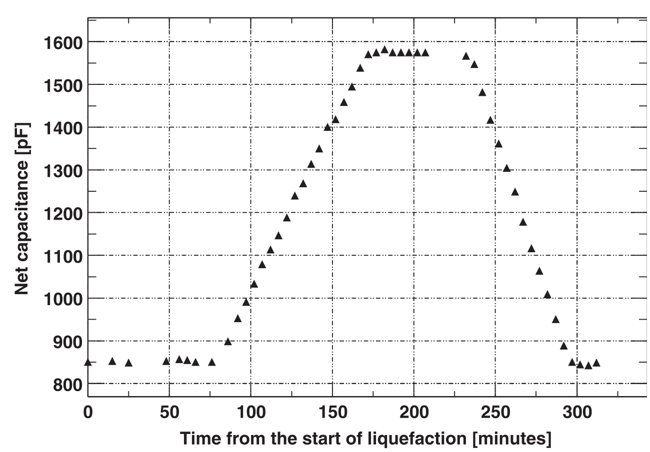

Fig. 4. Net capacitance of the level meter operated in liquid xenon. We tried to liquefy and remove xenon with a constant rate.

We checked that the meter did not contaminate liquid xenon using a liquid xenon ionization chamber as a purity monitor. The level meter of this type will be used in the liquid xenon gamma ray detector for the project to search $\mu \to e\gamma$.

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