Influence of External Magnetic Field on the Performance of Cold Cathode Gauges

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Abstract

A cold cathode gauge is used to monitor the pressure of the vacuum chamber during the operation of the SRC sector magnet. To examine the effect of environmental magnetic field on the performance of cold cathode gauges, the experiment using an electromagnet was carried out. The result showed that the pressure measurement with a cold cathode gauge was possible, although the change of indication due to the increase of an external magnetic field was large at a low pressure.

1 Introduction

We plan to use a nude B-A gauge and a cold cathode gauge (CCG) to measure the pressure of the vacuum chamber of the RIKEN Superconducting Ring Cyclotron (SRC). A B-A gauge is used during the non-operation period of the SRC; a CCG is used during the SRC operation, since a B-A gauge is no use in a large leakage flux of the SRC sector magnet. The operation of a CCG makes use of the ionization by electrons trapped in an electric field and a magnetic field. Being constructed with a permanent magnet, a CCG is expected to be usable even in a large external magnetic field, by aligning it in parallel to the lines of the external field as precisely as possible. Measurement of pressure using a CCG under an external magnetic field is actually reported [1]. In this paper we describe the changes of pressure indication for two kinds of CCG's available at a market when an external magnetic field is loaded using an electromagnet.

2 Experiment

2.1 Vacuum Gauge

Since the pressure required for the beam chamber of the SRC is estimated to be of the order of 10^{-6} Pa [2], a vacuum gauge used in the SRC beam chamber is needed to have a minimum measuring range which is one order or more lower than the order of the required pressure. Therefore, we chose two types of CCG's as follows: (1) Balzers: IKR060 and (2) Leybold: PR36.

2.2 Experimental setup

A schematic diagram of the experimental setup is shown in Fig. 1. A turbo-molecular pump (TMP. Osaka Vacuum, Ltd.: TH300) was set on a frame beside the electromagnet for evacuating to ultra-high vacuum. A variable leak valve (VLV) and a mass flow meter (MFM) were connected with the chamber to vary a chamber pressure. The two types of CCG's were mounted at the end of the vacuum pipe extending from the side of the chamber and were placed in

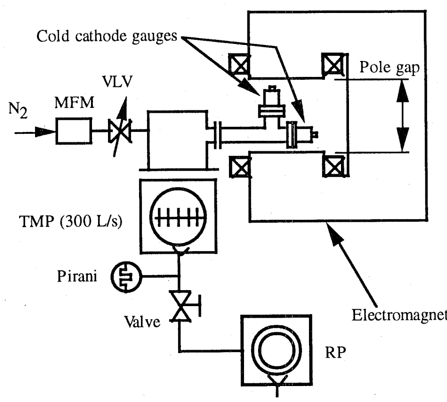

Fig. 1 Schematic diagram of the experimental setup.

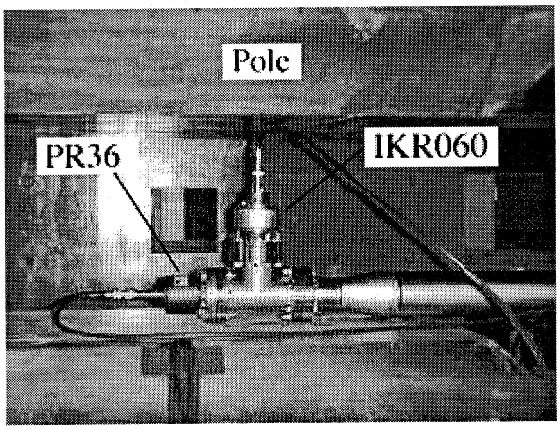

Fig. 2 Appearance of the CCG's in the pole gap.

the pole gap of the electromagnet. Figure 2 shows the configuration of the CCG's in the pole gap for testing in a uniform region of the external magnetic field. Both CCG's were laid so that the direction of magnetic fields generated by the permanent magnets coincided with those of the external magnetic field. For testing in an external magnetic field with a gradient, the CCG's were placed away from the pole gap at around the pole edge by shifting the whole apparatus all together.

2.3 Experimental method

Pre-evacuation for degassing the chamber was carried out before the measurement. In this operation, ultimate pressures of 1.6×10^{-6} Pa and 1.9×10^{-6} Pa were indicated with IKR060 and PR36, respectively. The fluctuations of PR36 indication were often observed which were supposed to be due to instability of gas discharge. The magnetic field gradient at the place where the CCG's were set for the testing in a non-uniform external magnetic field was estimated from another field measurement to be about

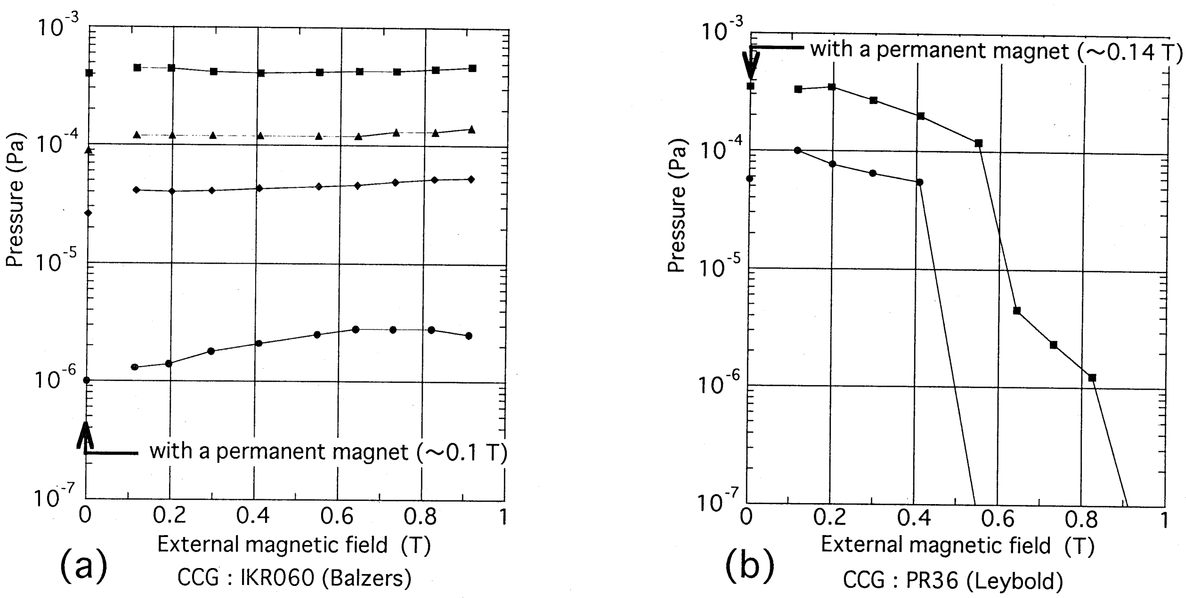

Fig. 3 Change of pressure indication as a function of the field near the CCG's without a permanent magnet when the external field is uniform: (a) IKR060 and (b) PR36.

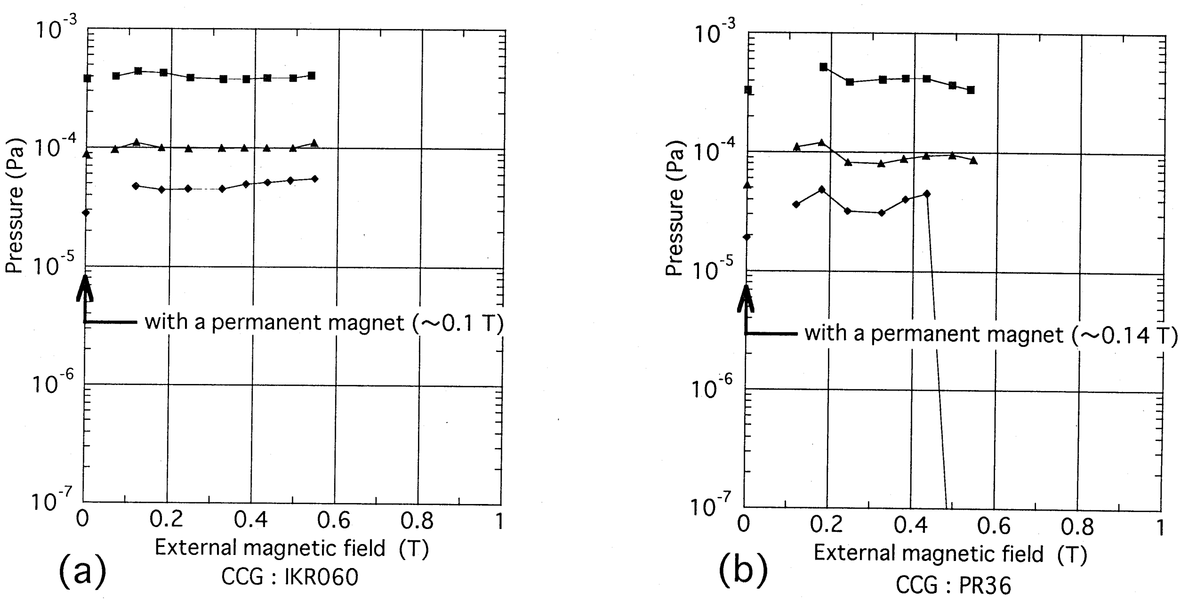

Fig. 4 Change of pressure indication as a function of the magnetic field near the CCG's without a permanent magnet when the external field is not uniform: (a) IKR060 and (b) PR36.

-0.74 T/m at the pole-gap field of 1 T. The leakage flux at around the TMP was estimated to be as small as 6×10^{-3} T at the pole-gap field of 1 T. We judged that this small field would have no effect on the performance of the TMP.

The measurement was performed under the following four conditions: (1) without a permanent magnet and in a uniform external magnetic field, (2) without a permanent magnet and in a non-uniform external field, (3) with a permanent magnet and in a uniform external field, and (4) with a permanent magnet and in a non-uniform external field. For the measurement without a permanent magnet, the pressure at a zero field was measured using a permanent magnet. The magnetic field at the pole-gap center was increased from 0.1 T. The pressure was changed by adjusting the flow rate of nitrogen gas into the chamber with the VLV and MFM.

3 Experimental results

Figure 3 shows the change of pressure indication as a function of the field near the CCG's without a permanent magnet when the external field is uniform. Only when the external field was zero, the pressure was measured using CCG's with a permanent magnet. In the case of IKR060, the change of indication is small although the indicating value increases as an external field increases at a low

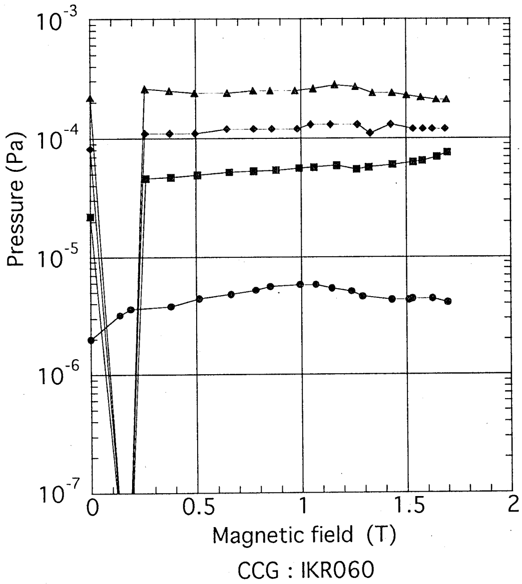

Fig. 5 Change of indication as a function of the magneticfield near IKR060 with a permanent magnet when the external field is uniform.

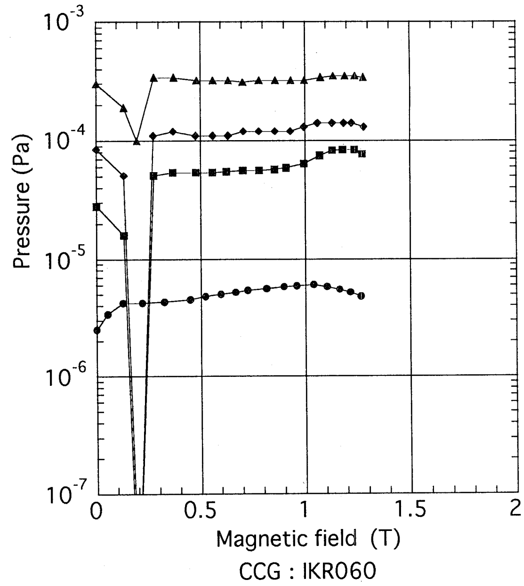

Fig. 6 Change of indication as a function of the magnetic field near IKR060 with a permanent magnet when the external field is not uniform.

pressure. In the case of PR36, the indicating value decreases rapidly as an external field increases, and finally the measurement becomes error. During the measurement the fluctuation of indication and/or the representation of lower limit on the meterpanel were found when the pressure at a zero field was below 2×10^{-5} Pa. This phenomenon is considered to come from the instability of gas discharge.

Figure 4 shows the change of pressure indication as a function of the magnetic field near CCG's without a permanent magnet when the external field is not uniform. In the case of IKR060, the tendency of the change is similar to the result obtained in a uniform magnetic field. In the case of PR36, the change of indication is more stable than that obtained in a uniform field, but is still larger than that for IKR060. The cause of this instability is considered to come from that the axis of PR36 was not aligned precisely in parallel to the lines of the external field, since the position of PR36 was more or less away from the median plane of the magnet (see Fig. 2).

Figures 5 and 6 show the change of pressure indication as a function of the magnetic field near IKR060 with a permanent magnet. The results in the case of a uniform field are shown in Fig. 5. It can be seen from this figure that when the pressure at a zero field was above 10^{-5} Pa the pressure indication decreases suddenly in the range of 0−0.25 T eventually the measurement becomes error. Above 0.3 T, the change of indication is small. The results in the case of a gradient field are shown in Fig. 6. It is seen that the change of indication shows a similar tendency as in Fig.5.

Conclusion

We judge that we can use CCG's in the leakage flux of the SRC sector magnet unless we will pursue a precise measurement. It would be better to use a CCG without a permanent magnet because the environmental magnetic field during the SRC operation is expected to be approximately below 0.3 T, in which range the measurement with a permanent magnet becomes error for unknown reasons. However, we still need to figure out a problem that the measurement without a permanent magnet becomes error when the environmental field is very small (0−0.1 T).

Acknowledgement

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