§18. Degradation Mechanism of Electrical Insulation System of a Superconducting Coil

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1. Introduction

In this project, the authors have been working on electrical insulation issues of a superconducting coil for the last three years. We focused on degradation mechanism of insulation system this year. The work covers subjects on [1] electrical breakdown phenomena of coolant liquid that is contaminated with metallic or carbon particles, [2] effects of coil quench and resultant thermal bubbles on electrical breakdown and [3] characteristics of partial discharge (PD) generated in a void in a solid insulation system. This year, special efforts were made to clarify [1] effects of conducting particles on insulation performances of superfluid liquid helium (HeII) and [2] void PD characteristics under transient surge stress. Data obtained in this project would be useful for electrical insulation design of LHD coils in Phase II, in which superfluid liquid helium will be employed as liquid coolant as well as electrical insulation medium.

2. Results

2.1 Effects of conducting free particles on breakdown characteristics of superfluid liquid helium [1)]

In Phase II of the LHD project, superfluid liquid helium (HeII) will be employed as liquid coolant as well as electrical insulation medium. It is expected that significantly low viscosity of HeII influences behavior of metallic free particles, which may contaminate HeII. It was found that basic characteristics, such as particle levitation dc field, particle motion between electrode gap, micro discharge caused by particle contact with an electrode, are similar to those of liquid nitrogen, which had been studied our previous research projects. However, we have newly found with liquid helium that gaseous bubbles were generated by the micro discharge. In normal liquid helium (HeI), generated bubbles rise up in the electrode gap and last for a long time. On the other hand, bubbles in HeII shrink immediately after micro discharge maybe due to enhanced cooling effect. Breakdown voltage of liquid helium contaminated by a metallic practice V_B is lower than that of pure liquid measured with a point to plane electrode system V_L. Pressure dependency of V_B is shown in Fig. 1. It should be noted that a discontinuity exists around λ point. These findings imply [1] the micro discharge electrically connects a metallic particle to the electrode to form an equivalent point electrode which generates a high electric field in the gap, [2] a bubble generated by micro discharge can be a weak point of entire electrical insulation system and [3] bubble growth is suppressed in HeII.

2.2 Void PD characteristics under transient surge stress and effects on insulation lifetime [2)]

Dc superconducting coils used in the LHD are energized by power source equipments which contain a lot of power electronics circuits such as a inverter. Transient surge voltages, which are generated by the inverter circuit, may influence PD characteristics and resultant electrical degradation process of solid insulation system. This year, we focused on effects of a transient voltage waveform on lifetime characteristics of a solid insulation. As a preliminary experiment, PD characteristics and insulation lifetime of epoxy resin containing an artificial void were investigated at room temperature. It was found that insulation lifetime became shorter increasing a high frequency component of a test voltage waveform (Fig. 2). Increasing high frequency voltage component produces more partial discharges in the void but does not influence the charge quantity.

References

1) Shinohara, T., Suehiro, J. and Hara, M., Proc. of Research Meeting on Electrical Discharge (in Japanese), ED-01-7 (2001) 37
2) Kurihara, T., Tsuru, S., Suehiro, J. and Hara, M., Proc. of 10th Asian Conf. on Electrical Discharge (2000) 123

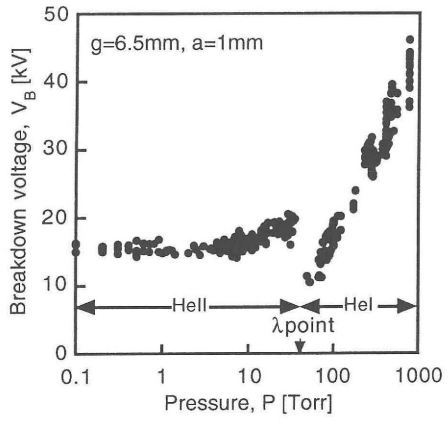

Fig. 1. Effects of pressure on breakdown characteristics of liquid helium contaminated with a metallic particle. A spherical particle of radius a was set in a parallel plates electrode system of gap spacing g.

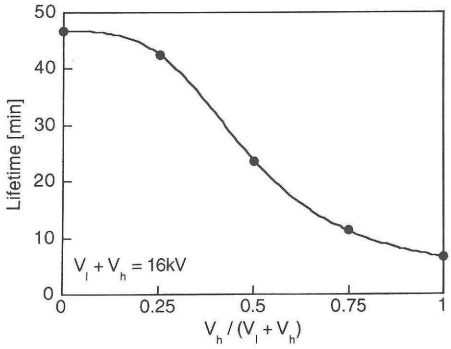

Fig. 2. Effects of high freaquency voltage component V_h on solid insulation lifetime degraded by void partial discharge at room temperature. V_l is low frequency component.