§ 34. Study of Composite Electrical Insulation at Cryogenic Temperature for Superconducting Magnet

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The world's largest class superconducting coil is used for the "Large-scale Helical Device". Its electrical insulation system might be exposed to considerably severe multiple stresses including cryogenic temperature, large mechanical stresses and strong magnetic fields. It is therefore very important to study its electrical insulation performance in order to establish the reliability of the coil. If superconductor quenches from superconducting state to normal state, the liquid coolant vaporizes very easily and turns into high-density gas at cryogenic temperature, which may reduce its withstanding voltage. Furthermore, it is very difficult to completely remove foreign particles out of the insulated space. So it is required to clarify the influence of foreign particles and electrification on the insulation performances.

1. Effect of foreign particles on breakdown characteristics of spacer surface in cryogenic liquid

This research was conducted using electrode system that simulated the insulation system in order to investigate the behavior of foreign particles and it's relation with the breakdown characteristics of insulation. The breakdown voltage when conductive particles were introduced between electrodes was about one fifth of that with non-conductive foreign particles, as shown in Fig.1. The conductive particles moved randomly above a 70% of breakdown voltage, and the breakdown occurred at the particles. The breakdown voltage with dielectric foreign particles retained nearly the same value as that with non-particles. The position of dielectric foreign particles was unmoved, or moved randomly between the electrodes and the breakdown positions were not affected by the existence of dielectric foreign particles. These results show the harmfulness of conductive foreign particles, but no serious problems due to dielectric foreign particles for electrical insulation properties.

2. Electrification of cryogenic liquid flowing electrical insulating pipe

It has been considered that liquid nitrogen is not electrified because it is an inert liquid. However, the electrification of liquid nitrogen flowing through a straight insulating pipe was confirmed by the present experiments. Relation between the average flowing rate of liquid nitrogen in PVC pipe and the amount of charge is shown in Fig. 2. The flowing rate was controlled by adjusting the pressure added to the liquid nitrogen container in the range of 0.1-0.4 kgf/cm^2. It was quite difficult to measure directly the velocity or the flowing rate of liquid nitrogen in the pipe, the average flowing rate was obtained by dividing the volume of liquid nitrogen by the time required to be stored. Pressure of 0.1, 0.2, 0.3 and 0.4 kgf/cm^2 correspond to average flowing rates of 7.8, 12.7, 21.7, 26.7 cm^3/s, respectively. The amount of charge increases with the flowing rate of liquid nitrogen and seems to saturate under larger lowing rate. It is suggested that higher flowing velocity of liquid nitrogen results in larger friction between nitrogen and PVC. The electrification of liquid insulants is known to reduce its breakdown voltage, so this problem must be studied further.

Reference
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2) Okada, H., Mizuno Y. & Minoda, A. , 2003 National Convention Record I.E.E. Japan, No. 2-055 (2003)

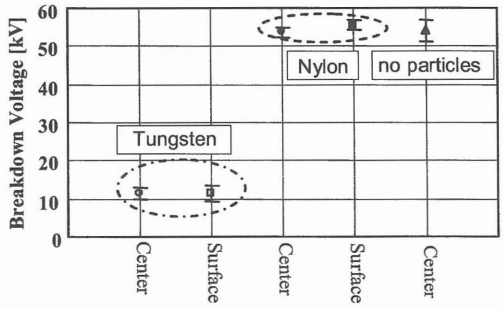

Fig.1 Breakdown voltage by entering foreign particle (2mm) in Liquid Helium

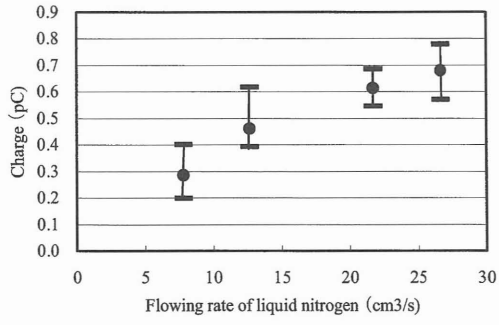

Fig.2 Effect of flowing rate of LN_2 on electrification