

DEVELOPMENT OF HIGH INTENSITY BEAM HANDLING SYSTEM
AT KEK-PS NEW EXPERIMENTAL HALL

PART III, DEVELOPMENT OF RADIATION HARD EQUIPMENTS

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Introduction

The criterion of design of the magnets for the new primary proton beam line was to realize a ten-year stable operation with the beam up to 1×10^{13} protons per second (pps). Thus the life time of the beam line magnets should be over the radiation dose of some 10^{10} Gy at least a factor of ten more than the conventional ones presently used in the KEK-PS[1]. The magnets placed just downstream of the target station require higher radiation hardness up to 10^{11} Gy. For such a case the magnet must be assembled without any organic materials. Therefore we developed two new types of radiation-resistant magnets for 10^{10} Gy and for 10^{11} Gy.

Polyimide magnets

For magnets for the radiation dose of 10^{10} Gy we employed the polyimide resin pre-impregnated (PRP) glass cloth to insulate the magnet coil. The radiation life of PRP is expected to be several ten times longer than conventional epoxy resin pre-impregnated insulators [2]. The radiation life of the PRP glass cloth was tested at the existing external proton beam line of the KEK-PS. The polyimide we used was BT (bismaleimide triazine) resin prepared by Mitubishi Gas Chemical Company Inc[3]. The test samples were strips of 5mm wide 50mm long and 0.25mm thick. The 12GeV protons were focused on the samples with 1cm² spot. Approximately 1.5×10^{12} protons were irradiated in every 2.5 seconds and 10^{10} Gy was achieved in 10 days (one experimental cycle).

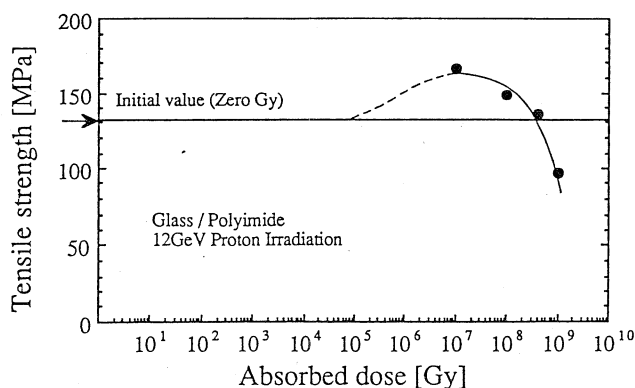


Fig. 1, Tensile strength of cured PRP glass cloth, plotted against the absorbed dose by 12GeV

proton irradiations.

The tensile strength was measured at the absorbed dose of 10^7 , 10^8 , 4×10^8 and 10^9 Gy. No serious fall-off of the strength was observed up to 4×10^8 Gy. However at 10^9 Gy the strength became approximately two thirds of the initial value. The results are shown in Fig. 1 and ensure the radiation life of PRP insulated coil over 10^{10} Gy. The breakdown voltage of the PRP insulator irradiated to 10^{10} Gy was also measured by a single-needle-plane test. Using DC voltages at the increase rate of 1kV/s and a needle with 1-3mm of radius of curvature the dielectric strength was found to be more than 400kV/mm. This value corresponds to 4kV/mm of standard AC break down test. This fact ensures also the radiation resistivity of PRP glass cloth over 10^{10} Gy. Most magnets of the new line were manufactured with the PRP glass cloth insulator. The glass cloth tape we used was 0.25mm in thickness and was wrapped in a double layer on the conductor so that the insulation thickness between conductors was 1mm. No other organic material was used in the magnet except for the PRP. Ceramic tubes were used for the electric insulation between the water manifold and the coil. Copper tubes were welded to both ends of the ceramic tube.

Cement magnets

For magnets for the radiation dose of 10^{11} Gy even the PRP must be eliminated. We assembled a small Q magnet (25cm in bore diameter and 40 cm long) from completely inorganic materials. The magnet coil was insulated by high-alumina cement (HAC) and asbestos tapes. First the hollow conductor was wound into a final Q-magnet coil shape without any insulators. The distance between conductors was temporarily kept by copper spacers 2mm in thickness as shown in Fig. 2. Second the asbestos tape was wrapped by hand after the spacers were removed. Inorganic ceramic bond [4] was used to fix the asbestos tape on the conductor as needed. Figure 3 shows the coil just before the filling with cement. The cement we used was mixture of 27% HAC 55% natural Al_2O_3 and 18% water by weight. The most crucial problem was how to eliminate excess water efficiently from the cement in the curing stage. In order to get mechanically hard cement with high electric resistance some suitable fraction of water must be eliminated from the cement surface. The solution we found was to make a cement bath of wood planks. The cement was poured into the wooden box in which the coil was placed and left 48 hours for curing.

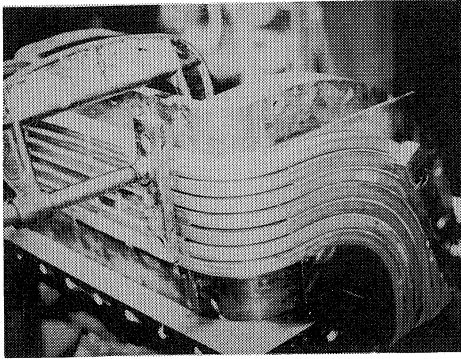


Fig. 2, Coil winding with copper spacers.

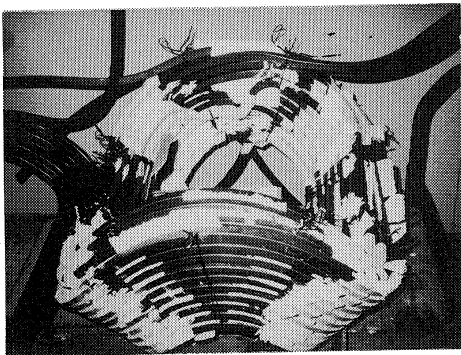


Fig. 3, Coil just before cement filling.

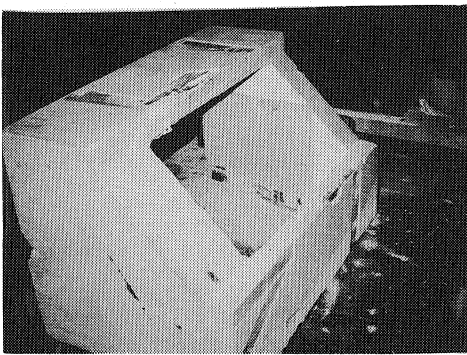


Fig. 4, Coil cured by the cement.

The drying stage was divided into two stages. The first stage was two days in a 120 °C oven and the second was also two days but in a vacuum tank. The electric resistance between windings of the coil was measured in each stage and $10^8 \text{M } \Omega$ was achieved at the end. Finally the coil was hermetically sealed in a stainless-steel casing. Figure 4 shows the coil before casing. The air in the casing was pumped down for additional two days and replaced by dry nitrogen. The pumping hole was sealed by metallic gaskets. The metalized ceramic tubes indicated in Fig. 5 were used as power and water lead-throughs to the coil. Since the completion of the cement insulated magnet there has been no electric break down in the last two years. Fig. 6 shows the front face of the magnet.

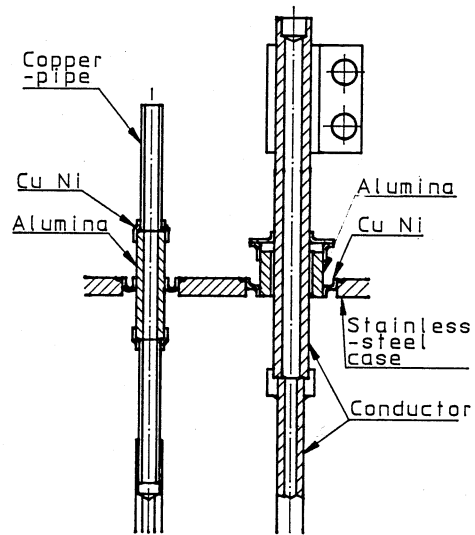


Fig. 5, Power and water lead throughs used in assembling the cement insulated magnet.

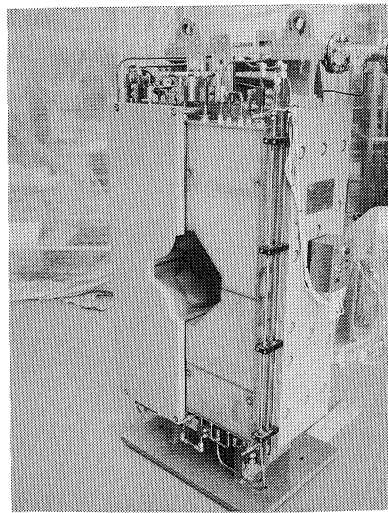


Fig. 6, Front surface of cement insulated magnets. The end plate of the magnet is temporarily removed.

References

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