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Development of the design technique with empirical scaling of vacuum insulation for electrostatic accelerators with large surface area and locally concentrated electric field for fusion application

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A design technique with empirical scaling has been developed in order to design a robust vacuum insulation on the 5-stage electrostatic accelerator with large surface area and locally concentrated electric field, aiming for the acceleration of 1 MeV, 40 A deuterium beams for fusion application. So far, there was no practical design technique and no applicable database of the voltage holding capability of electrodes whose surface area was several m2, which was one of critical issues on accelerators for fusion. Recently, the voltage holding capabilities of plane and coaxial electrodes have been widely investigated by the electrodes with the surface area up to 10 m2 which is directly applicable to the accelerator for fusion. In addition, voltage holding capability of electrodes with locally concentrated electric field has also been investigated by adjusting electrodes setup so that breakdowns occur at the corner where relatively strong electric field is generated. Based on the Clump theory showing a breakdown is triggered by EV = const, these experimental results have been integrated into the empirical scaling of allowable EV, such as EV$\propto$ S-0.33 for plane and coaxial electrodes, EV $\propto$ exp(-2x10-3 R) for the corner, where E and S are the electric field and surface area on the cathode, V is the sustainable voltage and R is the radius of the electrode. By taking into account the empirical scaling, the design technique has been developed in order to optimize the combination of the gap lengths and the surface area in multi-stage electrodes to maximize the voltage holding capability within the given boundary conditions of the geometry. By applying the design technique with the empirical scaling, the vacuum insulation of the 5-stage accelerator and its 5-stage high voltage busing have been designed and experimentally tested. As a result, the design voltage of 1 MV has been successfully satisfied in both cases, which shows the credibility of the technique. Moreover, these are easily applicable to not only the accelerator for fusion application but also general configuration of high voltage components in vacuum.

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