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Design and test of a module of a breathable Electrostatic Shield for the MITICA 1 MV negative Ion Beam Source

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The electrical insulation of the Negative Ion Beam Source at 1 MV is one of the challenging issues of MITICA, the prototype of the Heating Neutral Beam Injector for ITER. A collaborative effort between QST and Consorzio RFX is presently under way for assessing and optimizing this insulation [1]. According to extrapolation models based on recent reduced-scale experiments, the voltage holding capability of the single-gap vacuum insulation between the Beam Source (at -1 MV) and the Vessel (at ground potential) appears to be critical. However, the same models also show that the installation of intermediate Electrostatic Shields could effectively separate the single-gap insulation into 2 (or more) independent gaps, subjected to a fraction of the total voltage, and thus improve substantially the effectiveness of the Beam Source insulation [2]. A HV test campaign is already planned using full-scale mock-up electrodes, reproducing in detail the geometry of the Beam Source and Accelerator, under realistic operating conditions. In this campaign, the possibility of introducing an intermediate Electrostatic Shields (ES) surrounding the Beam Source (BS) is considered, so as to improve voltage holding by dividing the 1 MV vacuum gap in two independent insulating gaps of 400 kV and 600 kV respectively. However, the negative ion source in the BS shall operate with H2 or D2 gas at a pressure of ˜ 0.3 Pa (for optimal negative ion production), whereas in the surrounding vacuum insulation gas pressure shall not exceed about 0.04 Pa, to avoid Paschen- type discharges. Therefore, an ES having sufficient gas conductivity (breathability) is necessary to allow efficient pumping of background gas all around the BS. In order to avoid any reduction of the voltage holding capability due to direct shine-through effect and, at the same time, guarantee sufficient gas conductance, a modular structure with double-walls and staggered holes has been envisaged for the ES. The paper will present the criteria adopted for the design of a prototype ES module, with double-walls and optimized hole geometry (diameter and pitch of the holes, distance between walls) for maximum gas conductance. The results of voltage holding tests performed using the "breathable" ES module as intermediate electrode will also be presented and compared to those obtained in comparable reference configurations, with a flat intermediate electrode (no apertures) and also without intermediate electrode.

[1] G. Chitarin et al "Strategy for Vacuum Insulation Tests of MITICA 1 MV Electrostatic Accelerator," IEEE Transactions on Plasma Science (2022), https://doi.org/10.1109/TPS.2022.3168341

[2] N. Pilan et al. Fusion Engineering and Design 88 (2013) 1038–1041, http://dx.doi.org/10.1016/j.fusengdes.2013.02.071

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