§16. Long-Pulse Operation of a Cesium-Seeded Large Negative-Ion Source

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A high-power large negative ion source has been operated with a long pulse duration, aiming at long-pulse beam injection up to 10 sec in the LHD-NBI system. Since the ion source is operated with cesium seeded for the enhancement of the negative ion current and the lowering of the operational gas pressure [1], the operation stability and reliability are important for the long-pulse operation. The cesium-seeded operation was not influenced by a temperature rise over 100 ℃ of the plasma grid during the long-pulse arc discharge, although the negative ion current is dependent on the plasma grid temperature in a short-pulse (less than 1 sec) arc discharge operation. A long-pulse stable arc discharge is also important. Since the negative ion source utilizes a strong cusp and a filter magnetic field and these magnetic fields are distributed in the arc chamber, it is difficult for a high-power arc discharge to be maintained stably for a long period in a large arc chamber. By balancing individual arc currents flowing through each filament, a stable long-pulse arc discharge with an arc power of 100 kW was obtained over 15 s.

The most significant problem is the thermal load of grids. Since the negative ions accompany the electrons, which produce a thermal load on the downstream grid, the suppression of the accelerated electrons is important. A three-grid single-stage accelerator was used, where the extraction grid was shaped so that the secondary electrons generated on the extraction grid would be prevented from leaking into the acceleration gap. Figure 1 shows the thermal loads to the neutral beam dump, the extraction grid, EG, and the grounded grid, GG, as a function of the pulse length. A high-power negative ion beam of 330 kW (91 keV-3.6 A) was produced stably for 10 s from an area of 25 cm × 26 cm, where the current density was 21 mA/cm^2 and the negative ion power density was 1.9 kW/cm^2.

The neutralization efficiency of accelerated negative ions has been measured including the residual positive and negative ion ratios by water-calorimetry of the beam dumps. The neutral, the positive ion, and the negative ion ratios in the beam, estimated from the heat load of the beam dumps, are shown in Fig. 2. It is found that the result agrees well with the calculation result.

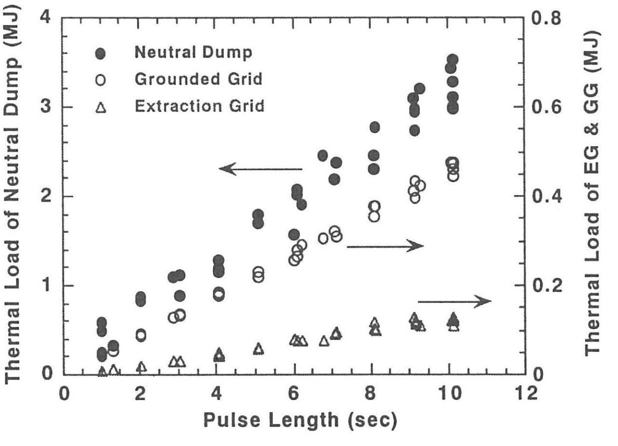

Fig. 1. Thermal loads to the neutral beam dump, the extraction grid and the grounded grid as a function of the pulse length.

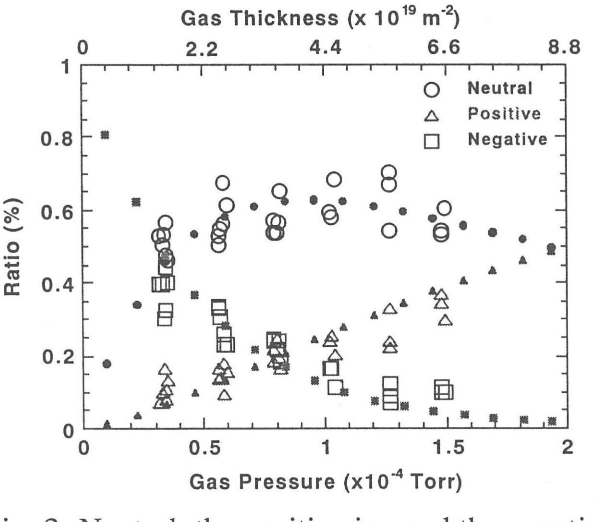

Fig. 2. Neutral, the positive ion and the negative ion ratios in the beam, estimated from the heat load of the beam dumps. Small closed symbols show the calculation results using the cross sections.

[1] Y. Takeiri, *et al.*, Rev. Sci. Instrum. **66**, 2541 (1995).