Electrostatic RID Experiment

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Introduction

The reference design of the residual ion dump (RID) for the ITER neutral beam injection (NBI) system is based on an electrostatic deflection of the residual negative and positive ions to in-line dump panels [1]. According to 4-channels beam line concept, RID forms four narrow (about 100 mm in width) vertical channels with the aid of 5 panels (1.8 m long and 1.7 m in height). Two middle panels are negatively biased with about 20 kV. This concept has the advantage of compact design with quite moderate power density (PD) load onto the panels – peak PD is less 8 MW/m^2. However, such a concept has never been tested in any working NBI system, all of them. use magnetic deflection systems with remote ion dumps.

Experimental investigation of the electrostatic RID concept is now started at the test stand IREK in the Kurchatov Institute. This experiment uses positive ion beam and two panels (one panel is under negative potential) which simulate the RID channel. In the ITER beam line the RID has to work in the presence of stray magnetic field with mainly vertical component, so the main physical question is in secondary electrons production and their behaviour in the crossed electric and magnetic fields, that can have an influence on the high voltage holding and state of operability. Hence, the experimental device panels are placed inside a special magnetic system which produces rather uniform vertical magnetic field in the RID volume.

System Description

Layout of the experimental injector stand IREK – T-15 injector prototype – is shown in Fig.1. The RID is mounted on a place of a previously used deflecting magnet.

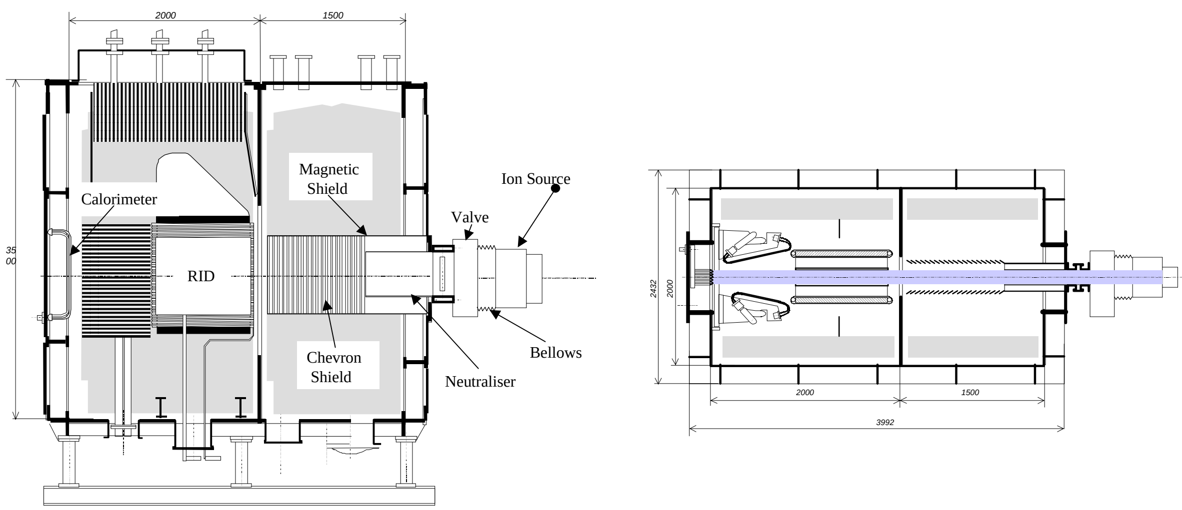

Fig.1. Layout of the electrostatic RID in the IREK test injector vacuum vessel

[1] ITER FDR, DDD 5.3, 2001

Ion source can produce a beam of positive hydrogen ions with maximum parameters 60 A/60 keV/1.5 s with use of multi-slit extractor 12x36 cm. The beam parameters for the RID experiment are chosen as:

- Ion source current 15 – 20 A
- Ion energy 35 – 50 keV
- Neutralisation efficiency 0.6 – 0.5
- Residual ion current 8 – 10 A
- Beam-on pulse duration 1 s

At a quite low extracted ion current density about 0.1 A/cm^2 the beam composition is approximately 0.45:0.35:0.2.

The neutraliser is equipped with a magnetic shield and between the neutraliser and the RID a chevron magnetic shield is placed for a gas flow out.

The experimental RID design is shown in Fig.2.

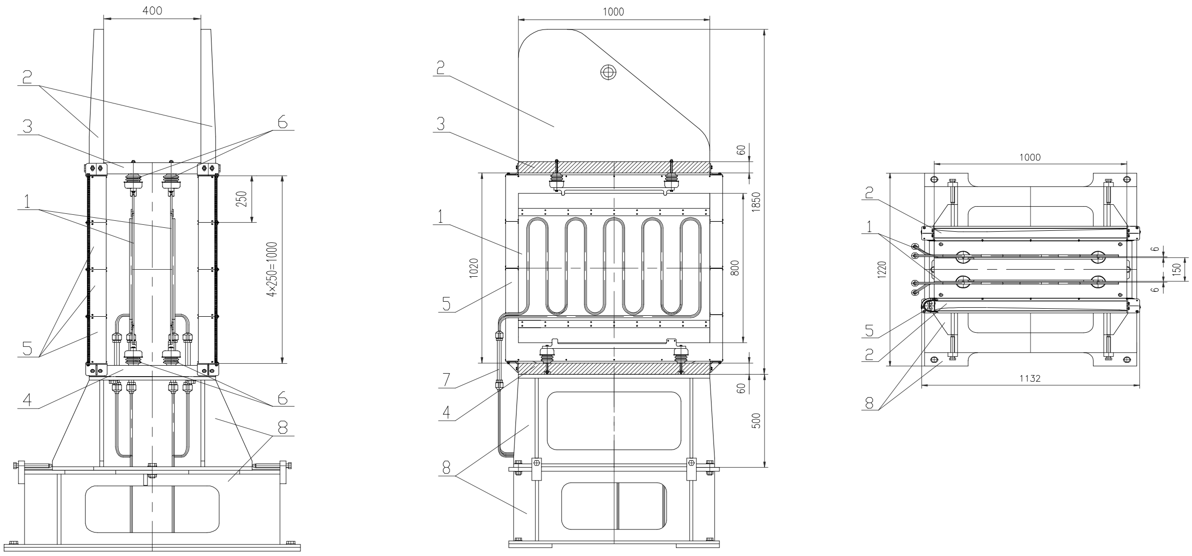

Fig.2. Experimental RID views.

1 – RID panels; 2 – Magnetic box side plates; 3, 4 – Magnetic box top and bottom yokes; 5 – Electro-magnetic coils; 6 – Support insulators with screen caps; 7 – Insulation break; 8 – Support frames.

It consists of two panels which form a channel, and a magnetic system. The panels are copper plates, each has cooling tube serpentine brazed to the plate on the back side. The panels are mounted inside the magnetic box on ceramic insulators which can keep high voltage (HV) potential higher 20 kV. Each panel has insulating breaks in cooling water circuits, water tubes feeds-through are under ground potential.

RID parameters			
Channel width	0.15 m	Negative deflecting potential	up to 10 kV
Panel axial length	1.0 m	Max. Power to the HV panel	600 kW
Panel height	0.8 m	Secondary electron emission	about 30 A

Thermal and stress parameters of the beam-dumping panel (6 mm thick) are calculated for the case of maximum power load density 4 MW/m^2. Calculations show that with 1 s beam-on pulse maximum temperature (about 180 C) and maximum equivalent stress (about 20 MPa) are quite moderate.

The secondary electrons are emitted from the negatively biased panel, which dump the residual positive ion beam, and are accelerated and captured by the grounded panel. Secondary electrons and ions are also generated in the RID channel volume by the fast atoms and ions in collisions with neutral gas (ionisation, charge exchange and stripping processes).

The RID magnetic system (MS) is to provide a vertical magnetic field (B_z) to simulate the ITER NBL conditions and to investigate the secondary electrons behaviour in the crossed ExB fields and their influence on HV holding. The secondary electrons drift in the ExB fields occurs when a cycloid height $h(cm) = 11.4E(V/cm)/B^2(Gs)$ becomes less than the channel width. For deflecting voltage U_d = 9 kV this requires B > 21.5 Gs.

Moreover, the MS is designed to produce B_z up to 130 Gs that gives an ability to carry out an investigation of the residual ion beam deflection in horizontal plane and its damping on the panels with use of the magnetic field only (Magnetic RID). The MS consists of two side plates and top and bottom yokes made of mild steel – the plates and yokes form a “magnetic box”. Four rectangular electromagnetic coils are mounted on each side plate (Fig.3). All the coils are electrically connected in parallel. Direction of currents in the left and right sets of coils is identical that gives the same direction of magnetic fluxes in the left and right side plates. Calculations with ANSYS-code show that such configuration provides very uniform vertical and horizontal distributions of B_z inside the magnetic box.

Fig.3. Photos of the RID magnetic system and the RID inside the IREK vacuum vessel (deflecting panel is on the right).

Parameters of the magnetic system				
Size of the “magnetic box”			Total number of the coils	8
	Width	0.4 m	Number of turns in the coil	95
	Length	1.0 m	Maximum current in one coil	30 A
	Height	1.02 m	Voltage	20 V
Plates and yokes thickness		60 mm	Maximum B_z	130 Gs

Measurements of the vertical magnetic field distributions in the RID magnetic system show (Fig.4) that B_z profiles and values are in good agreement with ANSYS-code calculations. One can see that horizontal and vertical profiles are very uniform inside the magnetic box. Axial profile demonstrates an influence of chevron magnetic shield when RID is installed in the IREK vacuum vessel (a distance between the chevron shield and MS is 0.3 m). The MS has a disadvantage – quite high magnetic flux out of the box sides, but this flux have not to influence on the beam transmission.

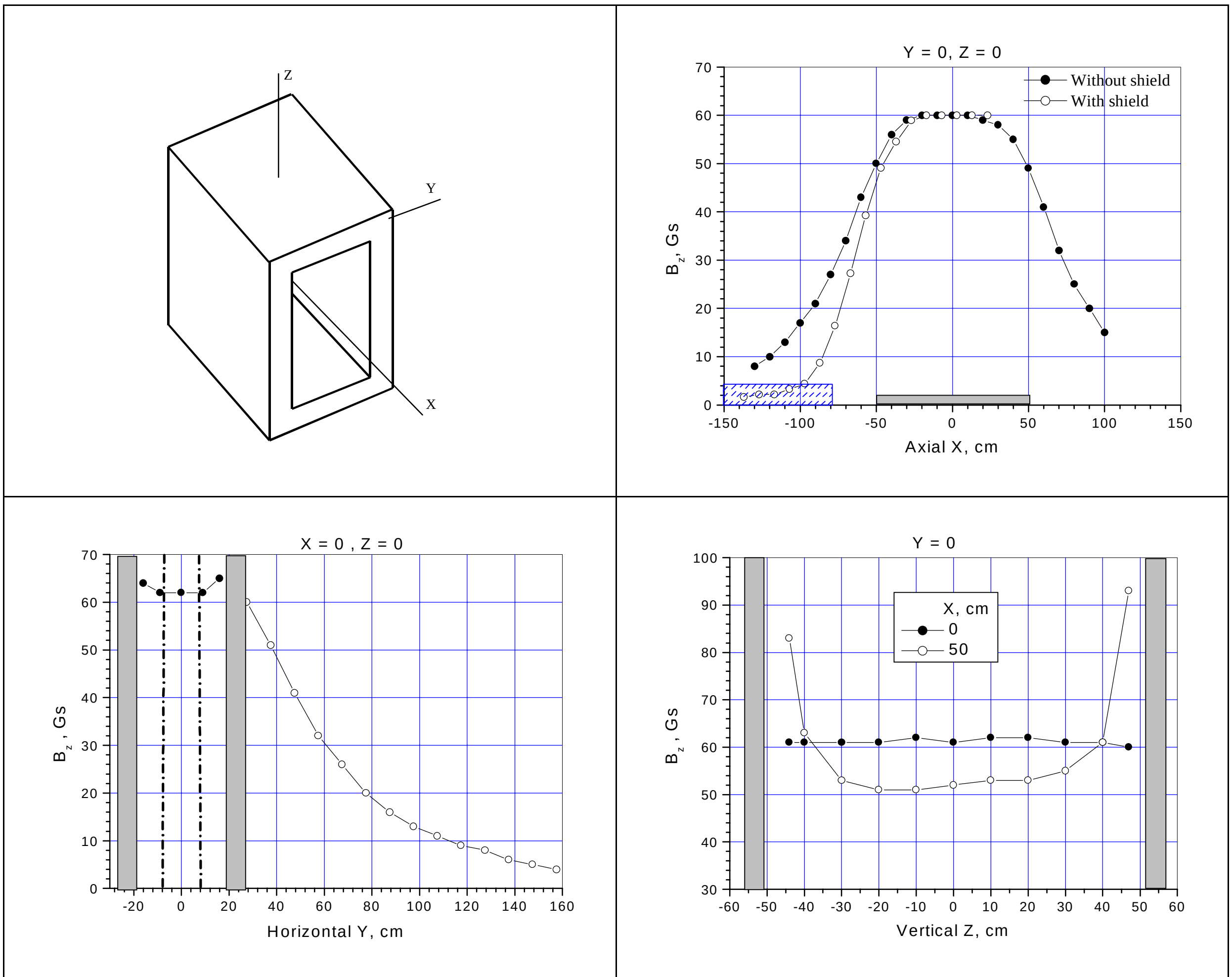

Fig.4. Experimental distributions of vertical magnetic field in the RID magnetic system for 14 A of current in one coil (112 A total).

First experimental results.

Initially the RID was tested on the voltage holding. Minus 10 kV was applied to the deflecting panel and hydrogen pressure was increased up to 20 Pa – no breakdowns was observed with an increase of magnetic field up to 100 Gs.

But with the beam on, breakdowns occur which initiate high current discharges, in these cases a protection system switches off the deflecting voltage. Two reasons were found in charge of: 1) a large outgassing from the panel and 2) the copper tubes were connected with stainless steel adapters with use of silver brazing and some silver marks were found out.

The silver marks were screened and panel conditioning was performed with use of magnetic deflection of the beam onto the panel. The HV conditioning is continuing with slow increase of U_d.