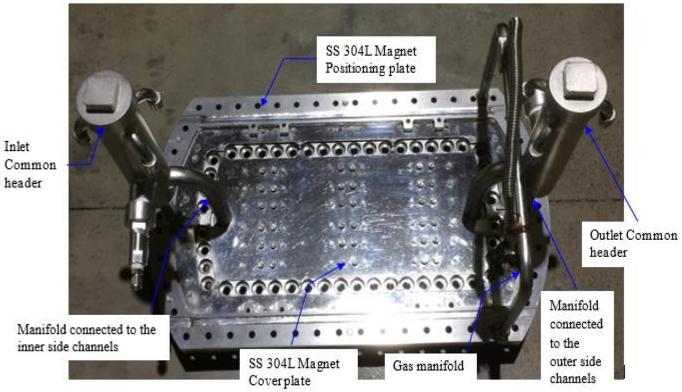
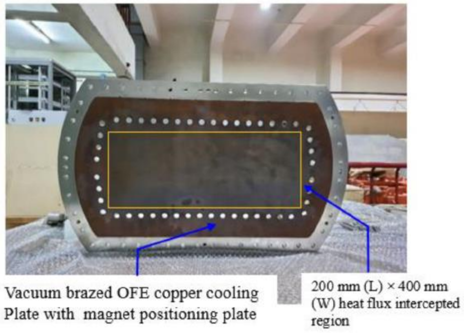
3D computational fluid dynamics analysis of PINI ion source back plate under high heat flux condition

Tejendra Patel, Mukti Ranjan Jana, Ujjwal Baruah



(a)



(b)

Fig. 1 (a) Fabricated Back Plate (b) Vacuum brazed OFE copper cooling plate with heat flux intercepted area.

- The Back Plate (BP) is an important component of the PINI ion source in the Neutral Beam Injection system, due to its several functions in ion source operation e.g. holding filaments and permanent magnets for plasma production and its confinement, giving vacuum integrity, and acting as a heat removal component.
- It consists of an SS304L Magnet Positioning, SS304L Magnet Cover Plate, and an OFE Copper Cooling Plate.
- The design of BP is very complex and its components are made up of dissimilar metals. Critical technologies are involved in the fabrication e.g. precision CNC machining, **Large Area Vacuum Brazing** of OFE copper cooling plate with SS 304 L magnet positioning plate.
- For steady state operation of PINI ion source, efficient cooling of BP is important to maintain the thermo-structural stability.

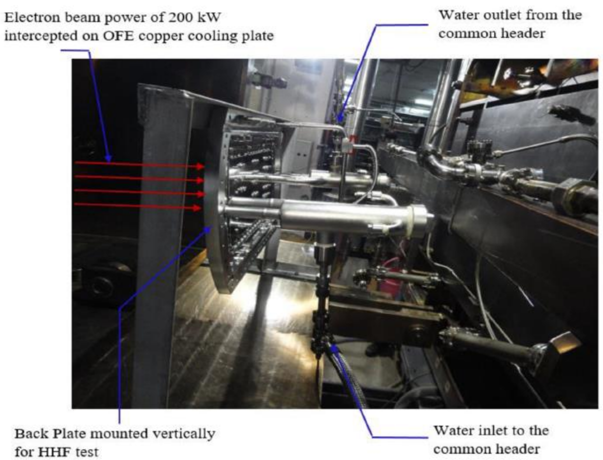


Fig.2 Back Plate assembled in Vacuum chamber at HHFTF Center, IPR.

- The PINI back plate is successfully fabricated by M/s Hind High Vacuum Pvt. Ltd, Bangalore, India). (Fig. 1)
- The Performance test has been done on PINI ion source BP with a heat load of 2.5 MW/m^2 at the High Heat Flux Test Facility Centre at Institute for Plasma Research (IPR) shown in Fig. 2.
- This heat flux is generated by an electron beam power of 200 kW intercepted on OFE copper cooling plate of size 400 × 200 mm^2, which covers all 35 inner cooling channels.
- The water of 1 kg/s mass flow rate at 34^o C is supplied to the common inlet header and distributed to the inner and out cooling channels of the OFE copper cooling plate.
- The surface temperature distribution of the OFE copper cooling plate has been recorded by an Infrared (IR) camera. Measured max. surface temp. 173^o C. (Fig. 6)

Source: Fusion Engineering and Design, 192 (2023) 113841 (1-12)
DOI: https://doi.org/10.1016/j.fusengdes.2023.113841.

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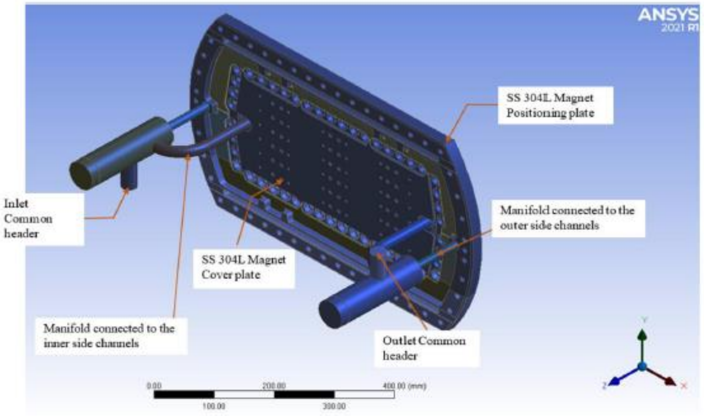

Fig.3 3D CFD model of the actual sized back plate

- The present study indented to do 3D Computational Fluid Dynamics analysis of the back plate under high heat flux condition using ANSYS R121. The realizable *k*-Ɛ turbulence model is used to solve the continuity, momentum, and energy equation of the flow. The present 3D CFD model is simulated by using a pressure-based solver as this solver is quite suitable for solving incompressible fluid flow problems. The momentum, turbulent, and energy equations are discretized by implicitly using the second-ordered upwind method.
- The following boundary condition are used: the heat flux of 2.5 MW/m^2 is intercepted on intercepted on OFE copper cooling plate within size of 400×200 mm^2; the mass flow rate of the cooling water and temperature are respectively 1 kg/s and 34 ^oC.
- During the high heat flux test experiment, it is observed that there are three temperature regions e.g. upper region (U) with max. temp of 173^o C , middle region (M) with max. temp of 118^o C , and lower region (L) with max. temp of 162^o C on the OFE copper plate (Fig. 4).
- The CFD analysis gives the surface temperature distribution over the OFE copper cooling plate with a maximum surface temperature of 174^o C at upper region (U), 97^o C at middle region (M) and 172^o C at lower region (L).
- The variation in maximum surface temperature between the upper and lower region is 6.4 % for HHFT result whereas that for the CFD result is 1.1 %. This shows that the CFD result is in good agreement with High Heat Flux experimental results (Fig.6).
- An important achievement of CFD analysis is to identify these three temperature regions (Fig. 4) and explained that this is due to the non-uniform distribution of water velocities (Fig. 5) in the cooling channels.

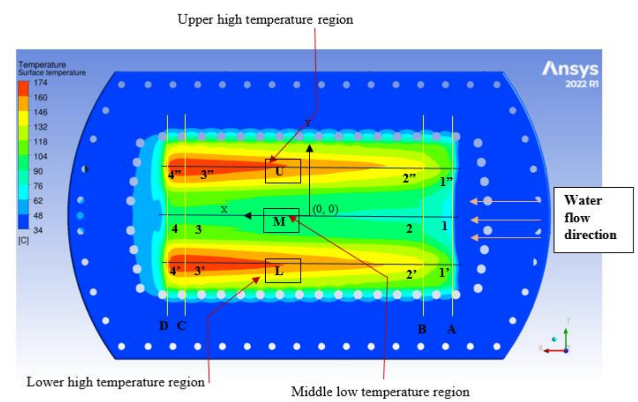

Fig. 4 Results of surface temperature distribution over OFE copper plate surface using 3D CFD BP model.

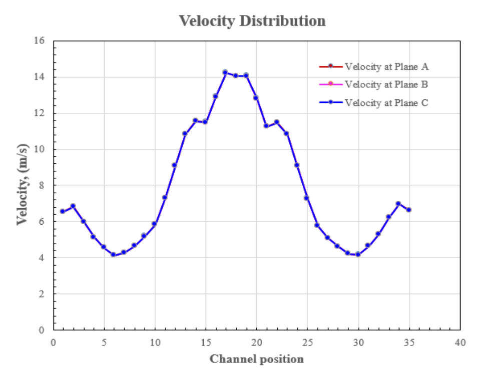

Fig. 5 Plot of average velocity distribution at the plane A, B, and C.

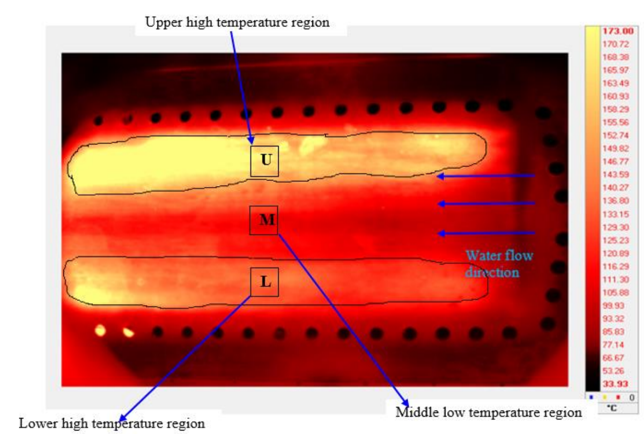

Fig.6 IR image of temperature distribution over the surface of the OFE copper

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