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The ITER divertor pumping system, design evolution, simplification and performance

Robert John Pearce*, Alexander Antipenkov, Bastien Boussier, Stephan Bryan, Matthias Dremel, Bruno Levesy, Christian Mayaux, Michael Wykes

ITER Organization, Route de Vinon sur Verdon, 13115 Saint Paul Lez Durance, France

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ABSTRACT

The ITER tokamak will be fuelled at a time averaged rate of up to 200 Pam^3 s^{-1} requiring neutralised gas in the divertor to be pumped to balance the fuelling and remove the fusion helium and other impurities in the exhaust. This is achieved on ITER using large bespoke cryo-sorption pumps. In this paper design evolution of the ITER divertor pumping system is outlined from the 1998 configuration to the current design. Details of the new, 6 direct pump, system design which will be used in the build of ITER are given. The operating modes of the new system configuration for different plasma scenarios are described and the performance of the new system is analysed and compared with previous baselines.

1. Introduction

The successful operation of ITER requires the largest, complex vacuum systems yet to be built. The vacuum spaces comprise the main tokamak (~1400 m^3, base pressure ~ 10^{-6} Pa), the cryostat vacuum for thermal insulation of the superconducting coils (~8500 m^3, base pressure ~ 10^{-4} Pa), four neutral beam injectors (total volume ~ 600 m^3, base pressure ~ 10^{-7} Pa) and auxiliary vacuums for diagnostic, radio frequency heating systems and cryogenic circuits.

The vacuum volumes on ITER are pumped by a set of around 400 vacuum pumps of 10 different technologies. These are serviced by a network of vacuum lines. All gasses with the potential of being radioactive are routed to the vacuum pumping room in the tritium plant building. Those which directly see the fuelling gasses such as the torus and neutral beam vessels form part of the closed fuel cycle.

The ITER tokamak will be fuelled with equimolar DT at a time averaged rate of up to 200 Pam^3 s^{-1} requiring neutralised gas in the divertor to be pumped to balance the fuelling and remove the fusion helium and other impurities in the exhaust [1]. This function provides the key design determining requirements on the design of the ITER divertor pumping system.

2. Pumping system evolution

The concept of batch regenerating cryopumps as the means to effectively pump the divertor has endured from the early design phases of ITER [2]. Other ideas and concepts have been considered but never assessed to be viable alternatives [3].

In the larger 1998 design, which had the same steady state fuelling requirements as today, 16 batch regenerated cryopumps were installed on the machine at the divertor level. The intention was that 12 would pump the torus while 4 were in a state of regeneration.

ITER was down sized and ways to reduce cost were found. In the 2001 baseline, there were 18 ports at the divertor level with 10 of these ports utilised to house cryo-pumps [4]. These pumps were planned to operate in a cyclic pumping/regeneration mode such that there were always 6 pumps pumping and 4 pumps in regeneration.

To reduce costs further and solve engineering issues associated with 18 divertor ports the number was halved and an additional 4 branched ducts were added. This resulted in the number of pumps being reduced to 8, these being configured with 4 on direct divertor ports (Fig. 1) and 4 on indirect branch ducts [5]. The planned normal operating mode, in this configuration, was to have 2 direct and

* Corresponding author.
E-mail address: Robert.Pearce@ITER.org (R.J. Pearce).

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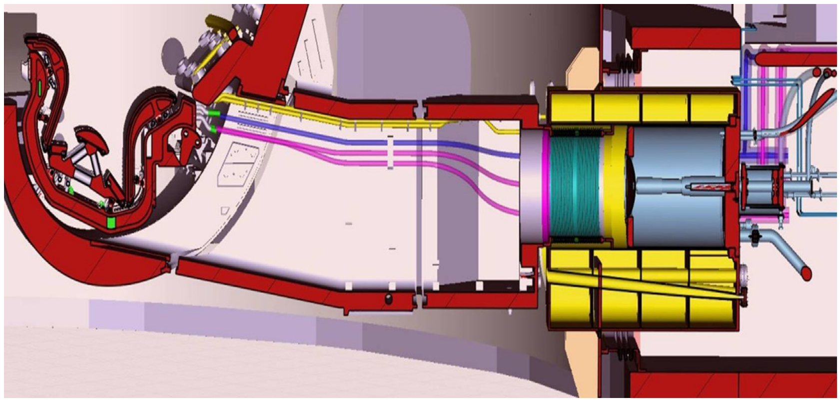

Fig. 1. Divertor pumping duct showing new cryo-pump housing.

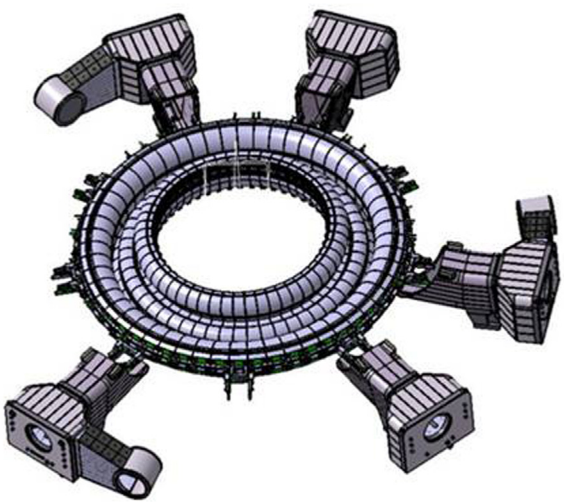

Fig. 2. View showing 5 direct and 3 branch ducts.

2 branch pumps always pumping and 2 direct and 2 branch always in regeneration. This configuration also evolved as requirements evolved and integration issues were solved. The configuration stabilised with 8 pumps, 5 on direct ports and 3 on branch ports (Fig. 2)

Further integration issues are solved and the design further simplified by the removal of the divertor branch ducts and realising a configuration of the pumping system using 6 out of the 9 directly connected divertor ports. In such a configuration for the most demanding fuelling rates, for long pulse operation, the pumping system will operate in a cyclic regeneration mode with 4 pumps pumping and 2 in a state of regeneration. The new configuration provides a number of operational advantages, improved performance in some areas and an acceptable minor loss of performance in other areas.

3. The design of the torus cryo-pumping system

The key elements in the design of the torus cryo-pumping systems, in addition to providing high integrity confinement, are: pumping speed, pumping capacity, tritium inventory, deflagration risks in case of leakage and operational reliability. The torus cryo-pump has been subject to development over the past 11 years and ITER is near to achieving a validated "build-to-print" cryo-pump design [6]. The final stage of development is underway to build and test a pre-production cryo-pump. The latest design of the ITER cryo-pump is given in Fig. 3. The cryo-pump has an overall weight of 8 tonnes. The pump plug diameter is 1.8 m and the overall cryo-pump length is about 3.5 m. Removal of the branch ducts does not change the cryo-pump design.

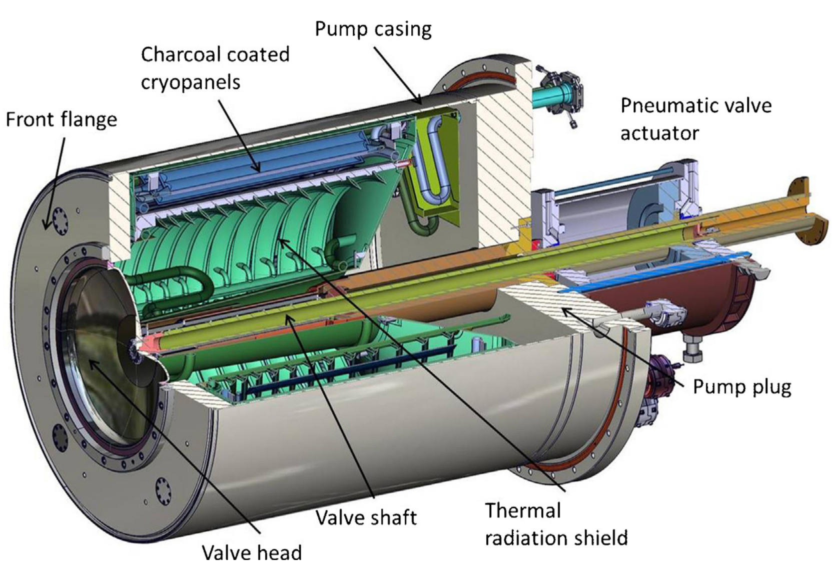

Fig. 3. View of the torus cryopump.