
EFDA–JET–CP(00)01/07

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Vacuum Pumping Developments on the JET Tokamak

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ABSTRACT

Mechanical high vacuum pumping requirements at the JET facility, have historically been satisfied by modified commercially available 3500l/s turbo-molecular pumps. These pumps have been used, over 17 years of experiments, but are now uneconomical to maintain due to obsolescence and tritium contamination. A novel adaptation of a new 2000l/s turbo-drag pump has been developed to meet the present and future requirements. Two of these pumps have been installed and are used to pump the torus. These pumps offer a number of advantages, and systems on JET will continue to be upgraded to incorporate such pumps. These should be an effective solution for other large fusion experiments.

1.0 INTRODUCTION.

JET is the world's largest tokamak and is the only one designed to operate with the deuterium/tritium (D-T) fuel mixture necessary for fusion power production. The vacuum vessel has a volume of $\sim 190\text{m}^3$ and is usually maintained at 320^0C . The main vessel is pumped by 4 turbo-molecular pumps and an internal cryogenic pump. An overview of the main vacuum systems is given in (fig1). A base vacuum of 5×10^{-8} mbar with an impurity partial pressure less than 5×10^{-9} mbar is typically achieved after vacuum conditioning. Significant quantities of tritium remain in the torus [1] after the D-T campaign (DTE1) in 1997 [2]. The vacuum system provides containment and pumping for tritium and other gas species used to fuel the plasma.

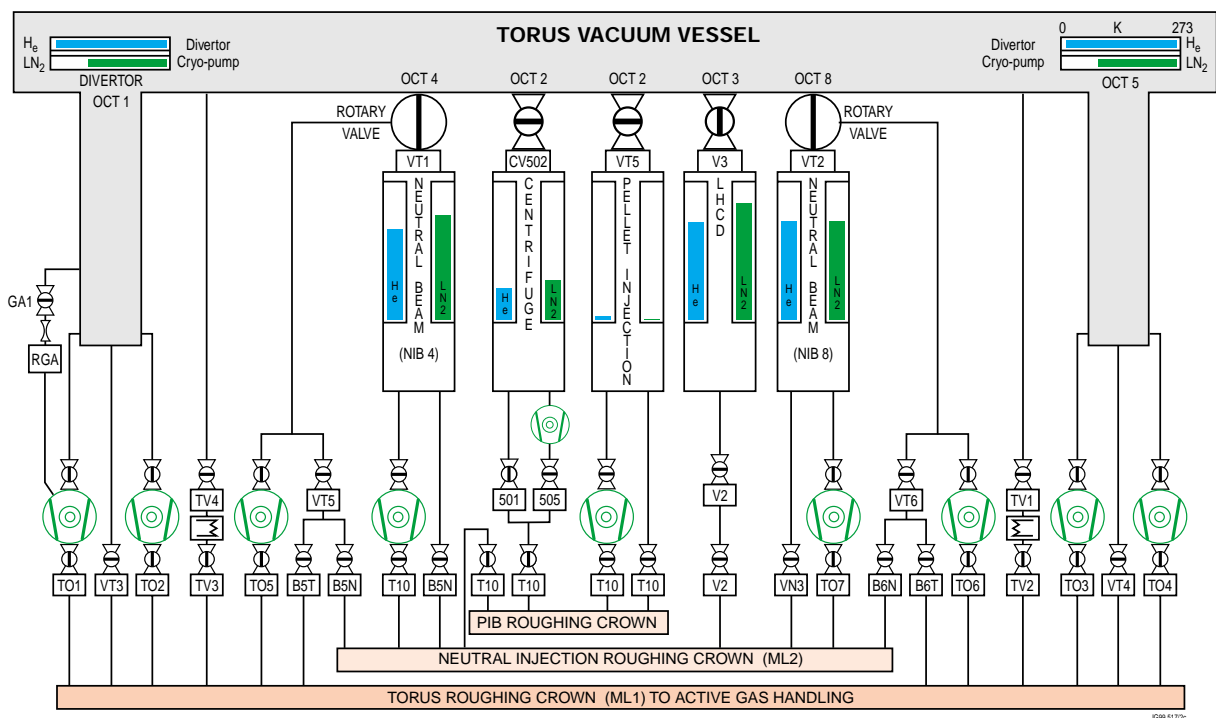


Fig 1 Overview of the Jet Facility vacuum pumping system.

The torus was originally pumped by four 3500l/s turbo-molecular pumps directly mounted to the torus pumping chambers [3]. The pumps were backed by rotary/Roots pairs outside of the torus hall, and gave a deuterium pumping speed of 7,000 l/s. The turbo pumps were adapted to meet the requirements of JET. Due to the inertial forces resulting from plasma disruptions, the spacing between the rotor and stator stages was increased and the pumps run 10% below full speed. The pumps were modified to enable full remote handling. Larger, tritium compatible oil reservoirs were also fitted to extend the life between oil changes.

In 1993 a pumped divertor was installed inside the torus, which used a large liquid helium internal cryogenic pump with a notional deuterium pumping speed of 130,000 l/s [4]. This pump dominates the vacuum pumping of deuterium but provides little pumping of Protium or Helium; these species are mainly pumped by the turbo-molecular pumps. Prior to DTE1, the Active Gas Handling System (AGHS) [5] was brought on line. Since then, the AGHS has provided the pumping on the backing line either by tritium compatible scroll pumps or by cryogenic fore-vacuum pumps.

Since DTE1, it has become uneconomical to maintain the turbo-molecular pumps. These pumps used oil-lubricated bearings traditionally changed after 10,000 hours run time. Tritium contamination of the turbo pump oil is now typically 6 GBq/l, making bearing changes non-viable. It has been found that 40,000 hours of running can be obtained before bearing problems occurred.

A novel adaptation of a new 2000 l/s turbo-drag pump has been made to meet present and future requirements. Two of these pumps have been installed and successfully used to pump the torus. This paper describes these new pumps.

2.0 THE 2000L/S TURBO-DRAG PUMP DEVELOPMENT AND ADAPTATION

Varian Spa. conceived a turbo-drag pump for the coatings industry with the expectation and adaptability to fill a niche in other markets. Sealed, permanently lubricated ceramic bearings provide 'dry' pumping. A monolithic milled rotor is utilised to provide both the molecular and drag pumping stages. The Gaede disc system provides 8 stages of drag pumping, giving a high gas compression ratio and enabling the pump to be effective with high foreline pressures.

The standard VT2000 pump has been modified to meet JET specification (fig 2). Original radiation requirements on JET were for compatibility with 10^6 Grays. This has since been revised down to 10^4 Grays. To comply with these levels modification are as follows: -

- The encasement design was changed to enable the use of all metal seals. Also the main electrical feed-through was replaced with one of flanged, welded, ceramic design.
- PTFE insulators inside the pump have been replaced with ceramic insulators, and location of the control electronics is outside of the biological shield.

- The bearing grease is specified to withstand 10^4 Grays.
- The backing line flange has been changed to enable compatibility with remote handling.
- Additionally, during plasma disruptions or under fault conditions, the torus can rise in potential. A galvanic isolation unit gives 1.25kV isolation between the control and AC drive electronics and the pump.

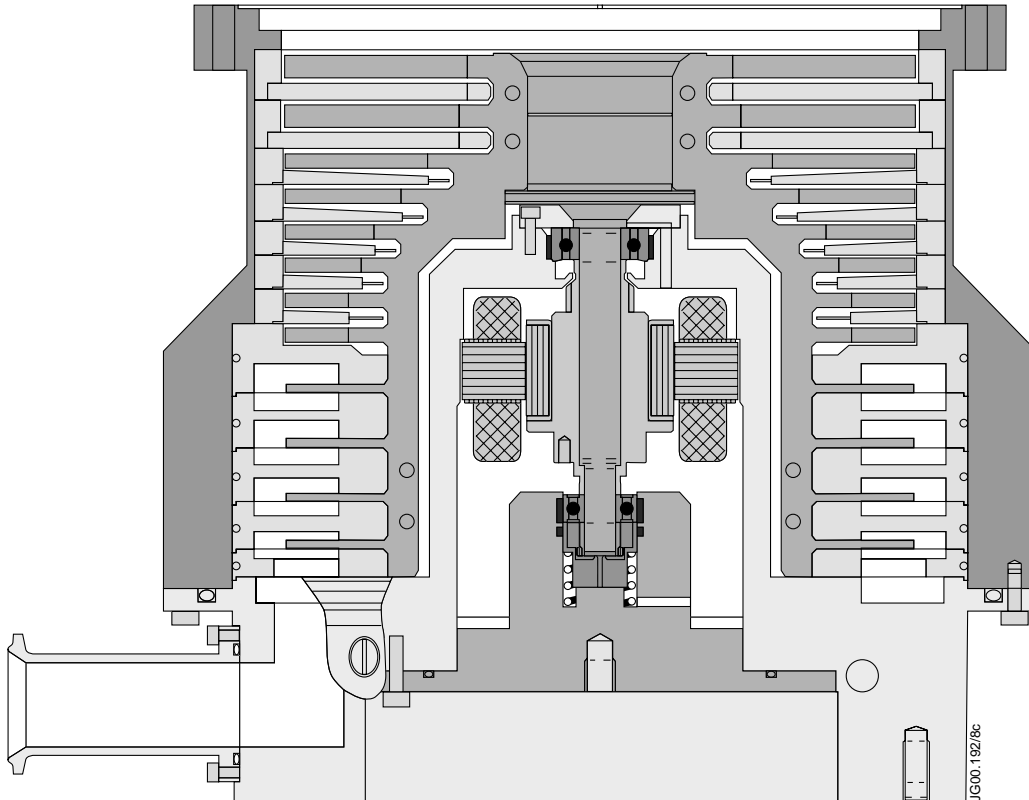


Fig 2 Cross section of the JET VT2000 turbo-drag pump.

3.0 INSTALLATION OF THE PUMPS ON JET.

A pump directly mounted on the torus could be subject to an axial or lateral acceleration of up to 100m/s^2 when the tokamak plasma disrupts. The bearing housing on the pump is held by silicon rubber rings which helps to avoid resonance in the pump but allows some axial movement of the rotor. The normal rotor speed is 33000rpm and the clearances around the Gaede discs have to be small, around 0.5 mm. An acceleration of above 40m/s^2 risks crashing the Gaede discs and hence destroying the pump. This problem was solved by decoupling the pumps from the torus. When the torus is baked, the pumping chambers move outward by up to 30mm. Movement of $\pm 15\text{mm}$ would cover the greatest movement in a disruption, however in order to provide a margin of safety $\pm 20\text{mm}$ is used for design purposes. The pumps are mounted on linear tables which give virtually friction free movement as the torus slowly expands or contracts thermally.

Movement of the linear tables is damped using an array of rotary dampers that ensure the pumps are held fixed during the high acceleration of disruptions. A bellows assembly above the pump accommodates the disruptive movements.

4.0 PERFORMANCE

Two of these pumps have been mounted on the torus (fig 3). The deuterium pumping speed plotted against inlet pressure for the two pumps is given in (fig 4) and compared with the remaining two old pumps. Pumping speeds are less than the nominal values for both pumps because of splinter shields above the pumps, conductance limitations of the installations, and in the case of the old pumps, the modifications to cope with plasma disruptions. At low pressure the new pump installation gives a reduction in the mechanical pumping on the torus of 18% compared to the old pumps. However above 5×10^{-3} mbar the new pumps provide improved pumping.

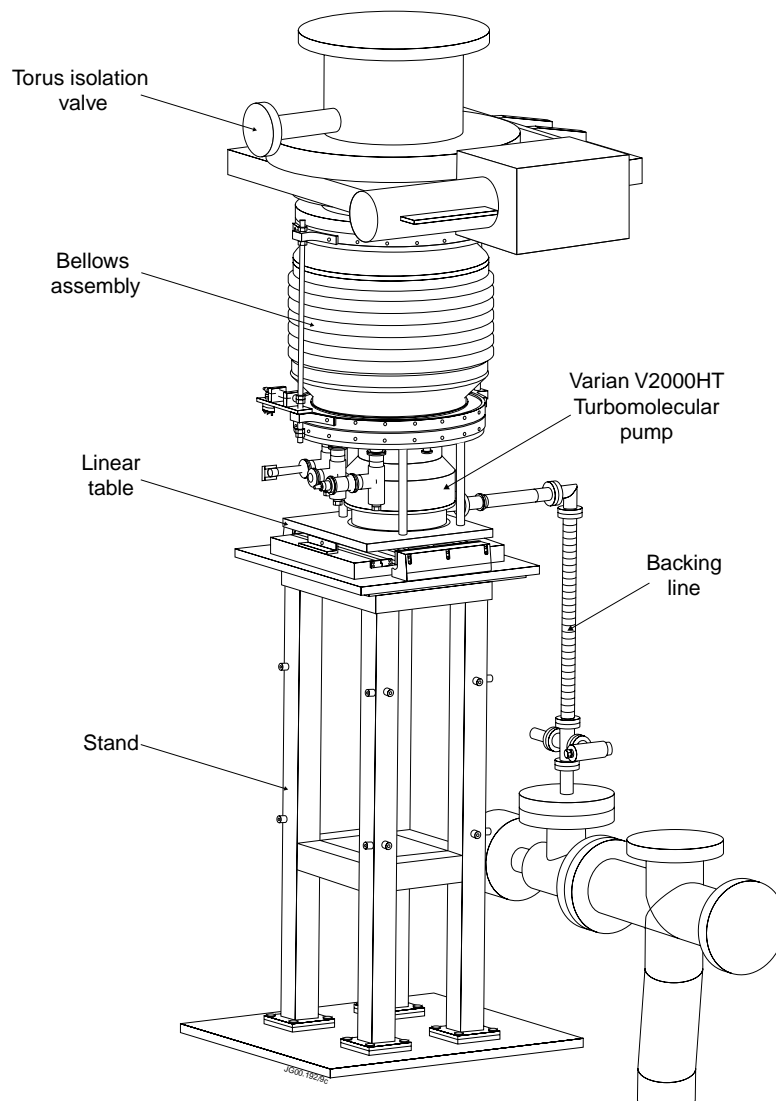


Fig 3 Pump Installation on JET

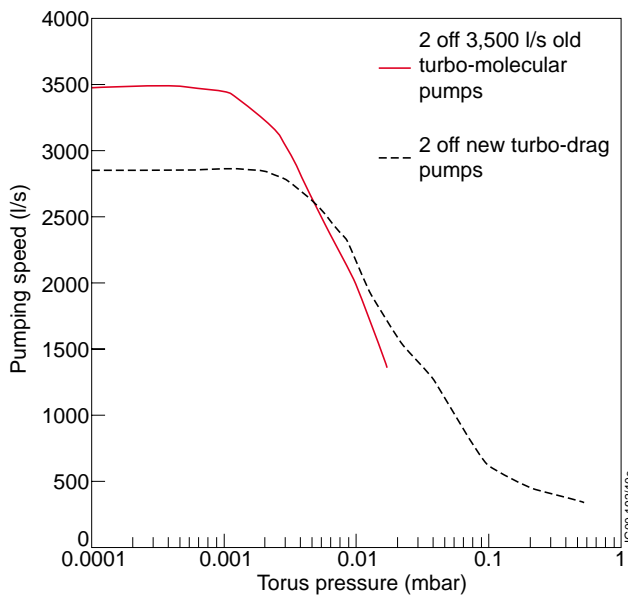


Fig 4 Pumping speed against torus pressure for two pumps.

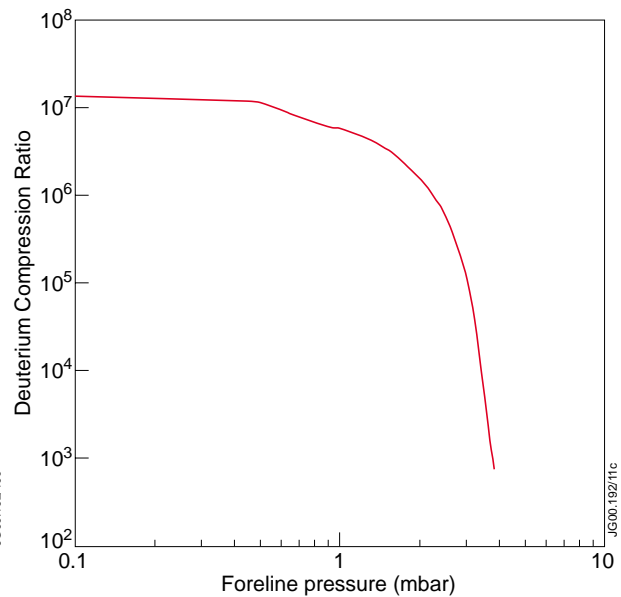


Fig 5 Deuterium compression ratio against foreline pressure for the VT2000 pump

The deuterium compression ratio for the new pumps against backing pressure is given in (fig 5). Compression ratio is almost two orders of magnitude higher than for the old pumps. This enables the backing pressure to rise to 1mbar with little effect on the torus pressure.

The pump movement during a disruption is compared to the vessel movement in (fig 6). The maximum acceleration of the pumping chamber was 40m/s^2 whereas the pump accelerates at $\sim 0.05\text{m/s}^2$ to come in line with the new resting position of the torus.

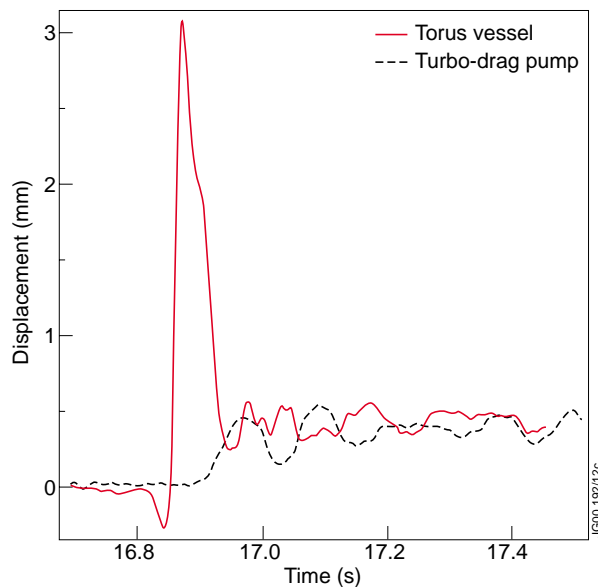


Fig 6 Movement of the pumping chamber / the turbo-drag pump for a plasma disruption.

5.0 ADVANTAGES OF THE PUMPS

The JET VT2000 pumps give a number of advantages over the turbo-molecular pumps previously used on JET: -

- The permanently lubricated ceramic bearings of the pump means that they can be treated as maintenance free without the problem of changing tritiated oil.
- The main components remain standard and can be produced in large quantities. Therefore additional manufacturing costs for the modified pumps are low.
- Deuterium glow discharge cleaning (GDC) [6] is most effective on JET with a torus pressure of between 3×10^{-3} to 1×10^{-2} mbar. Over this pressure range, the new pumps offer greater pumping speed, which improves the cleaning efficiency.
- Efficient Helium GDC was not possible with the AGHS backing the old turbo-molecular pumps due to the limited helium pumping speed of the AGHS. Efficient Helium GDC now requires less than 1% of the backing pumping speed previously required.
- In plasma operations and during Deuterium GDC, the AGHS cryogenic forevacuum pump is used to back the torus turbo pumps. Unplanned partial regeneration of these pumps causes gas to pass back through the old turbo-molecular pumps. The new pumps can sustain a foreline pressure of up to 4 mbar and hence provide a much higher degree of isolation for the torus from the forevacuum line.
- In the JET DTE1 experiments tritium permeation out of the torus was largely due to the long residence time of tritium at high pressure in the hot vessel, during divertor cryogenic pump re-generations [7]. The ability of the new pump to pump at higher pressure allows the regenerated gas to be directly pumped into an isolated room temperature forevacuum line where it can be analysed before being pumped by AGHS and processed. With four of the new pumps on the torus, the total tritium permeation for a future campaign with a similar amount of tritium injection to DTE 1 will be reduced by a factor of around 100.

6.0 CONCLUSION

New turbo-drag pumps have been installed and proven on JET. The installation offers a number of advantages over previous designs particularly during tritium operation. The pumps should prove to be an effective solution for other fusion experiments.

ACKNOWLEDGEMENTS

This work was performed partly in the framework of the JET Joint Undertaking and partly under the European Fusion Development Agreement (EFDA). The latter part was funded under the JET operation contract by EFDA.

REFERENCES

- [1] Andrew P, Brennan D, Coad P, Gibson A, Orchard J, Pearce R, Rossi A. Tritium recycling and retention in JET, *Journal of Nuclear Materials* 1999; 266-269:153-159.
- [2] A Gibson, Experience towards the operation of a fusion reactor gained through fusion experiments using deuterium-tritium mixtures in JET, *Fusion Eng. and Des.* 47(1999) pp107-113.
- [3] Duesing G, Proc, 1X IVC-V ICSS, Madrid (1983).
- [4] Obert W, et al, Performance of the JET pumped divertor cryopump system, Proc. 16th IEEE/NPSS Symposium on Fusion Eng. Illinois (1995) pp 742-745.
- [5] Lasser R, et al, Latest results of tritium commissioning of the JET Active Gas Handling Plant, Proc. 27th IEEE/NPSS Symposium on Fusion Eng. San Diego (1997) pp 292-296.
- [6] Pearce R, Andrew P, Bryan S, Orchard J Saibene G. The experience with JET's combined dc/RF glow discharge cleaning system, *Vacuum* 1996; 6-8:665-670.
- [7] Pearce R, et al, The JET Gas Baking Plant for DT Operation and Analysis of tritium Permeation and Baking Gas Activation in DTE1, *J. Fusion Technology* 1998; 2: 1001-1004.