Experiences and Challenges in Pumping the 200m3 vacuum chamber at JET

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Daresbury Labs, Warrington.

The Joint European Torus (JET)

Jet Torus specifications

Torus radius	3.1 m
Vacuum vessel	3.96m high x 2.4m wide
Vessel volume	180 m^3 - 200 m^3
Base Pressure	2 x 10^{-8} mbar
Operating Pressure	~ 10^{-3} mbar
Bakable to 320^{o}C.	Operate @ 200^{o}C

~120 ports with windows/diagnostics/ feed-throughs to the outside world

100's Kms of lip welds

Plasma temperatures upto 200,000,000^{o}C

⇒ The vacuum vessel has undergone radical changes since 1983

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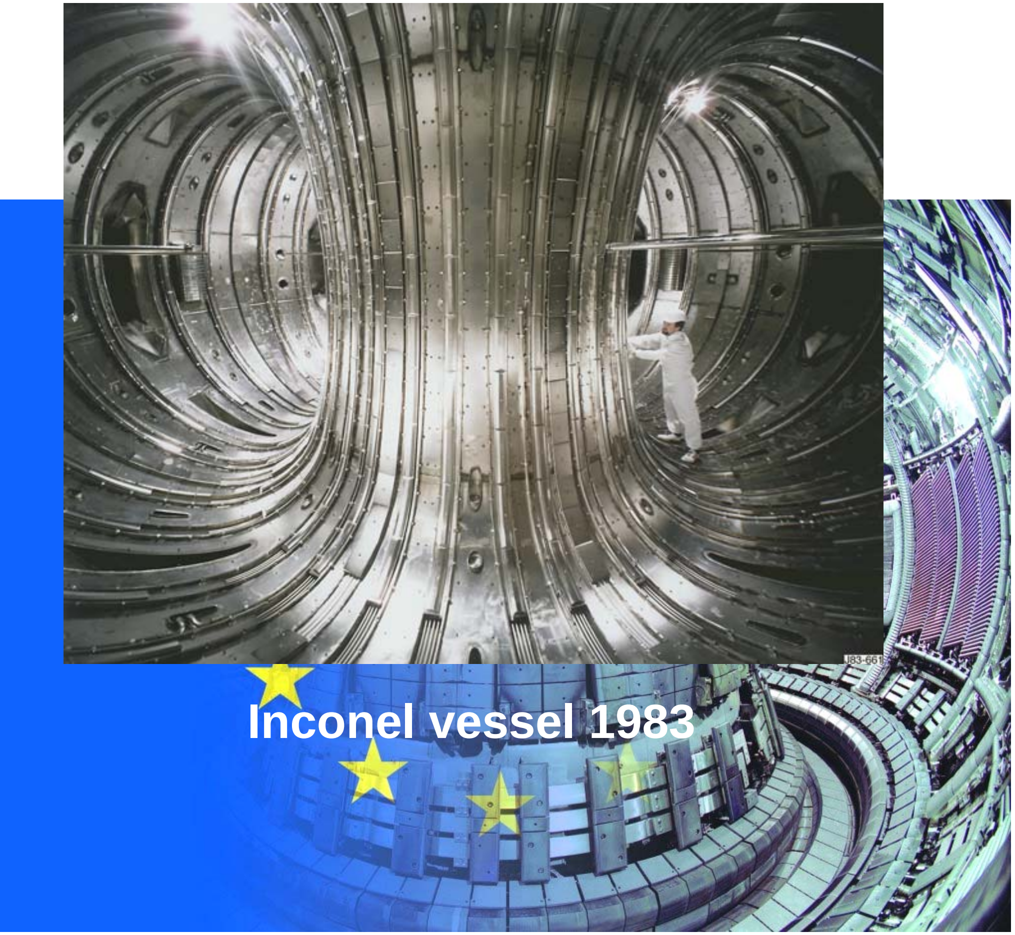
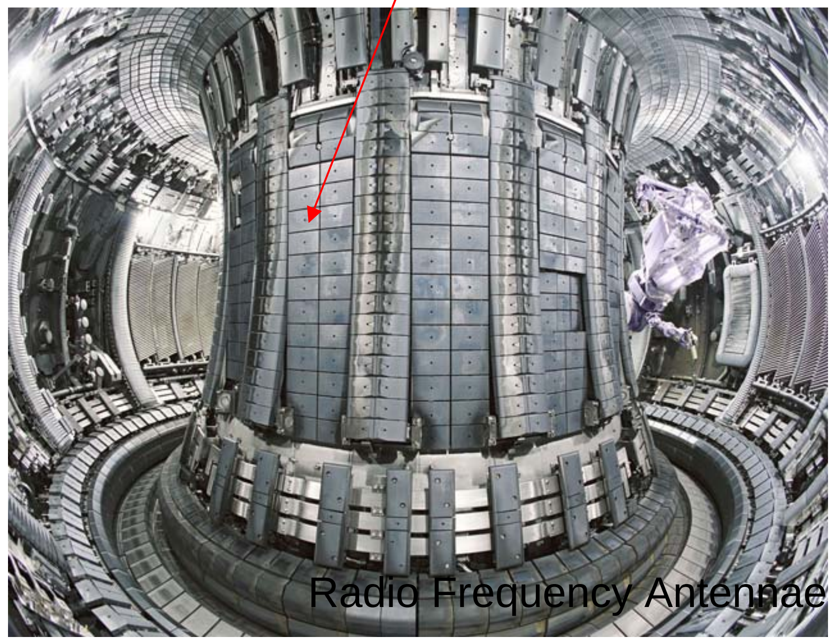


Vessel more recently

6 tonnes of composite carbon tiles
Surface area ~ 10^6 m^2



⇒ And there is more!

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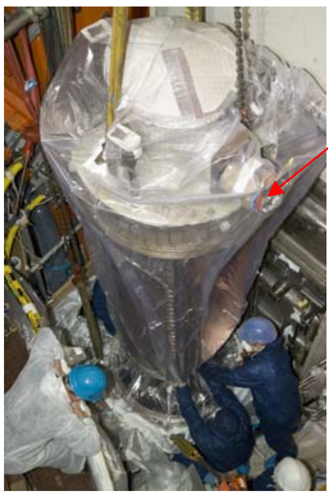
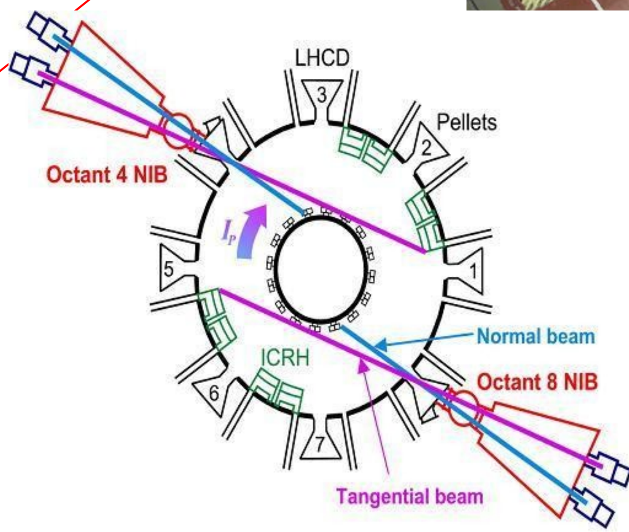
Neutral beam injector boxes NIB's.

2 Neutral Injector Boxes (NIB) at 50 m3 each.

NIB's provide additional heating to the plasma by way of injecting high energy neutrals of deuterium.

Have ability to be isolated from main torus vessel by large valves.





Several other devices with volumes > 5m^3.

Dozens of devices with volumes ~ 1 – 2 m^3

⇒ So, what does all this do?

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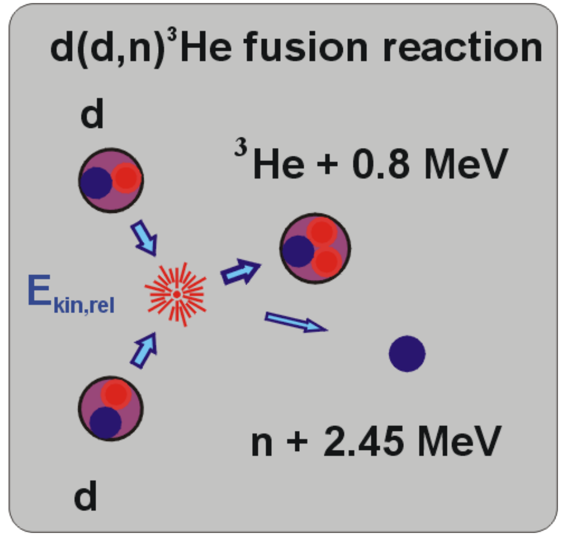
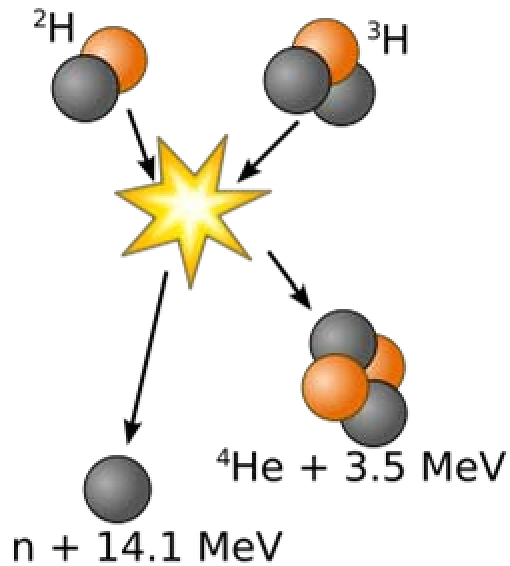
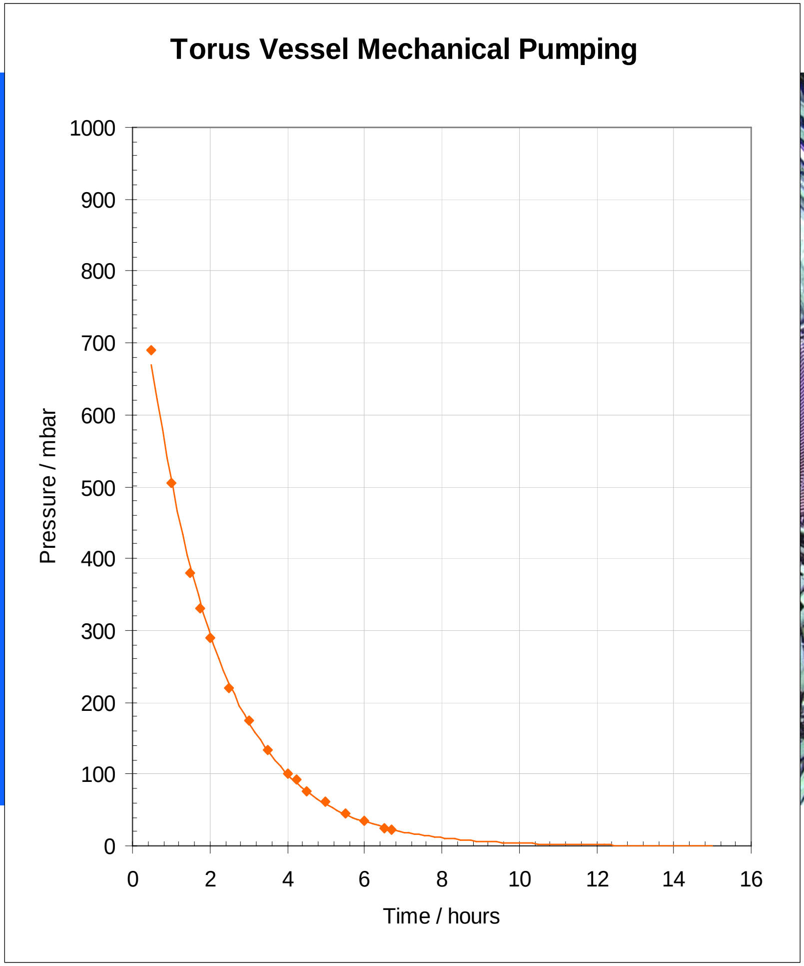




⇒ Creating the conditions to make fusion possible.

We use 3 methods of primary pumping. 1st mechanical roughing

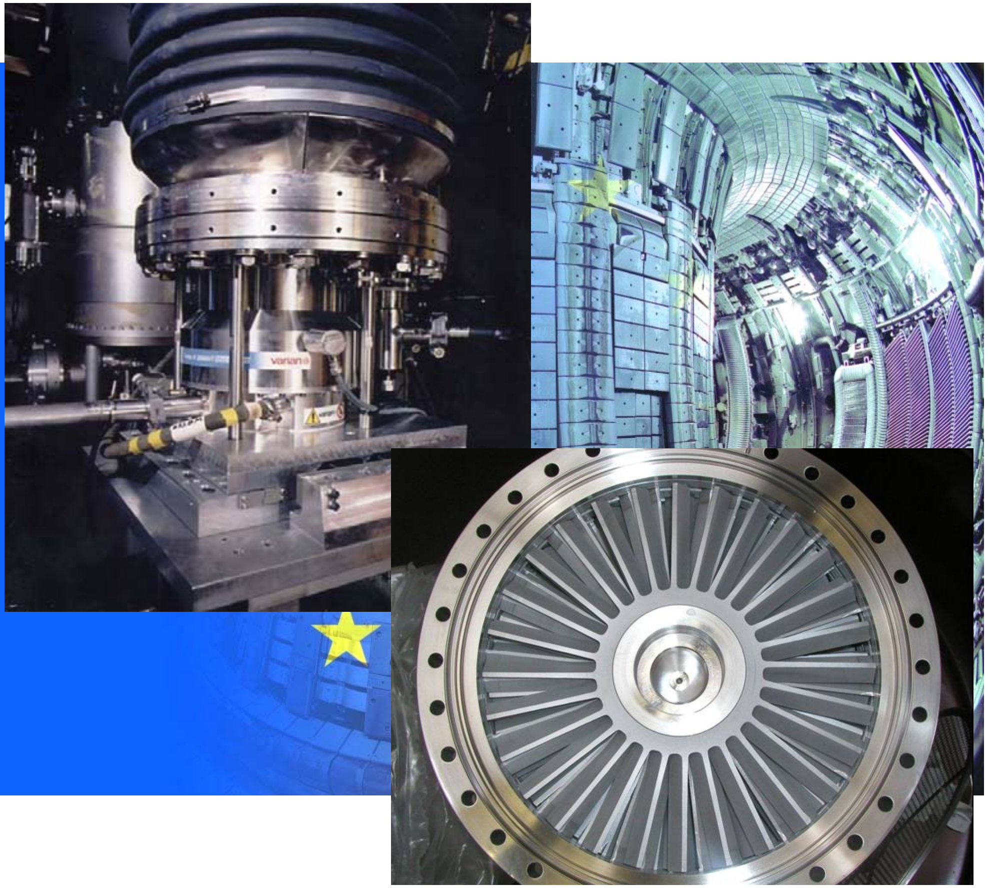


Our tritium capability means that exhaust gases must be carefully processed.
The gas processing is performed by our Active Gas Handling System (AGHS).
The AGHS facility is responsible for the mechanical fore vacuum system providing rough vacuum during initial pump down of the vacuum vessels or when large amounts of gas have to be pumped.

Vacuum exhaust gases are treated using an Exhaust Detritiation System (EDS) which uses a hot paladium based catalyst to convert hydrogen isotopes to water which is then easily removed from the exhaust gas.

⇒ Once roughed to ~ $5x10^{-2}$ mbar ~ 10hrs

2nd Turbomolecular pumping



- Four 2000 l/s turbo pumps on the Torus de-coupled mechanically from the Torus to avoid damage during vessel movement.
- One 2000 l/s turbo pump on each Rotary High Vacuum Valve.
- One 2000 l/s turbo pump on each NIB Box.

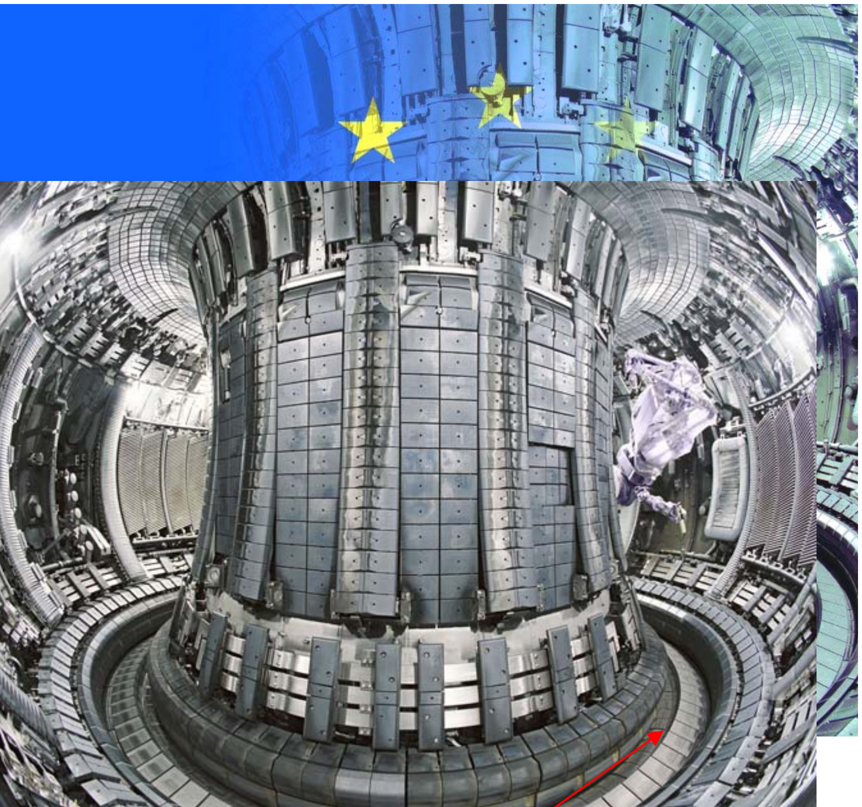
Majority of other vacuum systems on JET have 500 l/s turbo pumps.

The ultimate pressure for these pumps is typically 10-10mbar. However, in operation on JET the lowest pressure that they can normally achieve is in the region of 10-7mbar, because of the sheer size of the vacuum vessels and magnitude of the gas load from them.

$\Rightarrow$ last but not least

3rd Cryogenic pumping

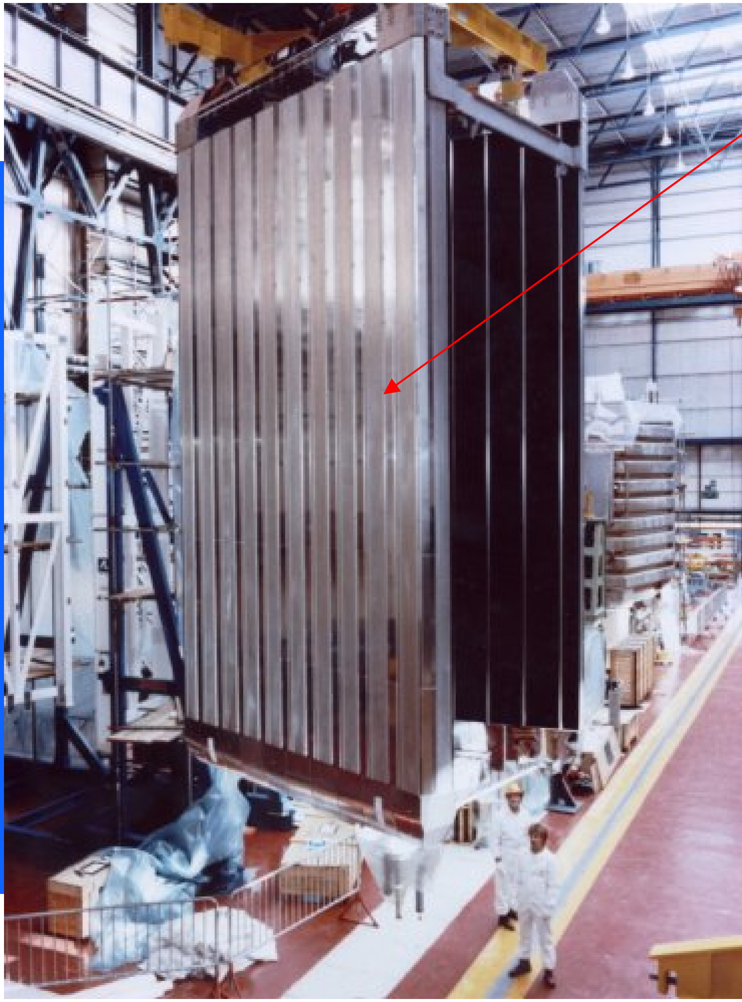
The Pumped Divertor (PD)

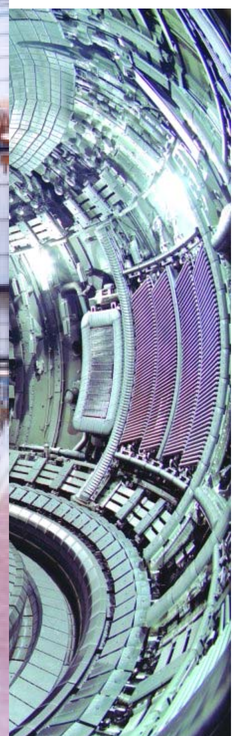


Pumped Divertor (PD)

The pumped divertor consists of two separate cryopanel systems underneath the divertor tiles at the bottom of the Torus. These two systems are always operated in tandem, and they provide a pumping speed of approximately 200,000 l/s during normal operation. This is 95% of the total pumping capacity that is available for the Torus. Although plasma operations are possible without the PD cryopanels in operation, it is unusual for this to be attempted. During normal operation the PD cryopanels and four turbopumps work together to maintain the high vacuum in the torus. The PD cryopanels are not cooled by normal liquid helium, but by 'super-critical helium'. This high pressure fluid is slightly warmer than normal liquid, but makes better thermal contact with the metal panels, cooling them more effectively without allowing formation of bubbles that can impede the flow through the coolant channels. This ensures that the panels operate at a more stable temperature.

$\Rightarrow$ **More Cryogenic pumping**





Neutral Beam Injector Cryopanel

Each NIB has a huge array of cryopanels providing a pumping speed of approximately 5,000,000 l/s in order to ensure that the neutraliser gas in the NIB does not drift into the torus where it would affect the vacuum conditions. Only the high power beams produced by the NIB can pass the cryopanels and through the rotary valves into the plasma. During normal operation, the NIBs are pumped solely by the cryopanels. After a period of operation (usually several days) the cryopanels are regenerated, and the gas that they release is pumped away to the active gas handling system by the turbopump.

⇒

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In a similar way to a domestic freezer, cryopanels can only collect a limited amount of gas before they have to be 'defrosted' or as we say 'regenerated'. To regenerate the panels we simply allow them to warm up in a controlled way, usually at night when JET is not operating. This releases the frozen gases which are pumped away to the active gas handling system by the turbopumps. Importantly, because most of the gases used in the JET plasmas are hydrogen isotopes, they are potentially flammable or explosive, so we have strictly enforced inventory limits for our cryopanels, set at a level that guarantees that we cannot collect enough gas to constitute an explosive hazard.

$\Rightarrow$ Additional vessel conditioning

Glow Discharge Cleaning (GDC)

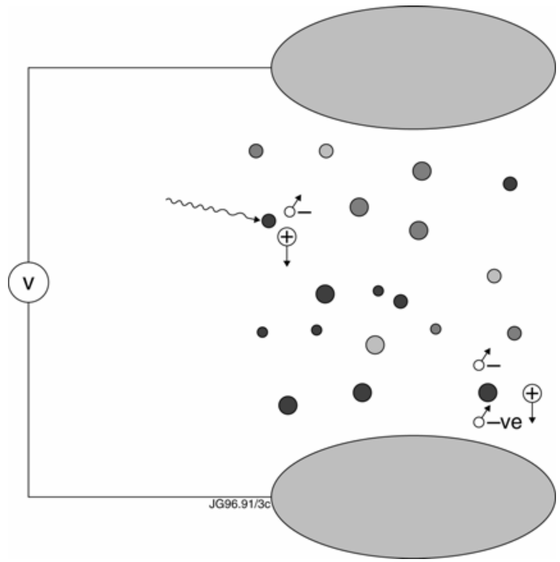
Potential is applied between a pair of electrodes in a vacuum and gas introduced.

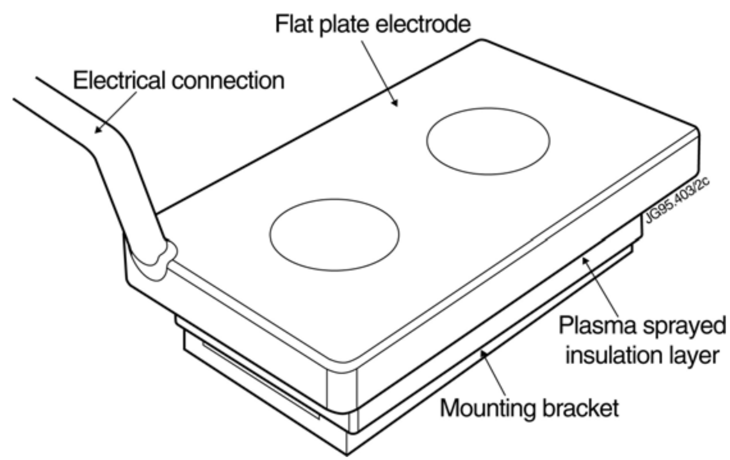
Free electrons accelerating towards the anode, on collision with atoms, produce ions and more free electrons.

The glow is struck (breakdown) when the product of the number of ions produced per free electron and the number of electrons emitted from the cathode (as a result of ion bombardment) is greater than or equal to one. This occurs when:-

The electrons have sufficient energy to ionize the relevant gas (i.e. high electrode potential, pressure not too high)

Once initiated the glow is maintained by reducing the potential between the electrodes (e.g. constant current).





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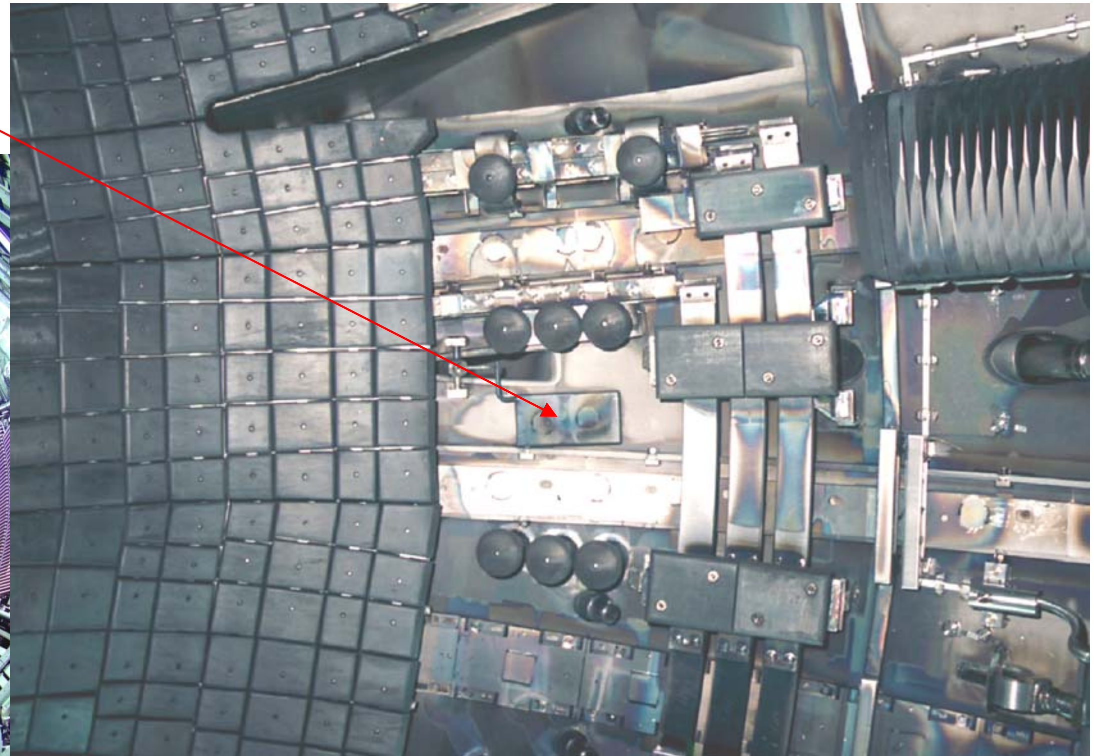

Four plate electrodes, mounted symmetrically at the top of the JET vessel.

Four individually controlled, DC (20A 1500V) power supplies with isolated outputs.

Dedicated gas introduction system.

Computer controlled sequence.

⇒ and finally

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We currently have the ability to evaporate Beryllium (Be).
Be is an excellent getter of oxygen. However, we are Replacing the whole of the plasma facing wall, currently carbon for Be so this facility will probably become redundant.

Actually, the most efficient method of maintaining clean vessel condition is the plasma itself.