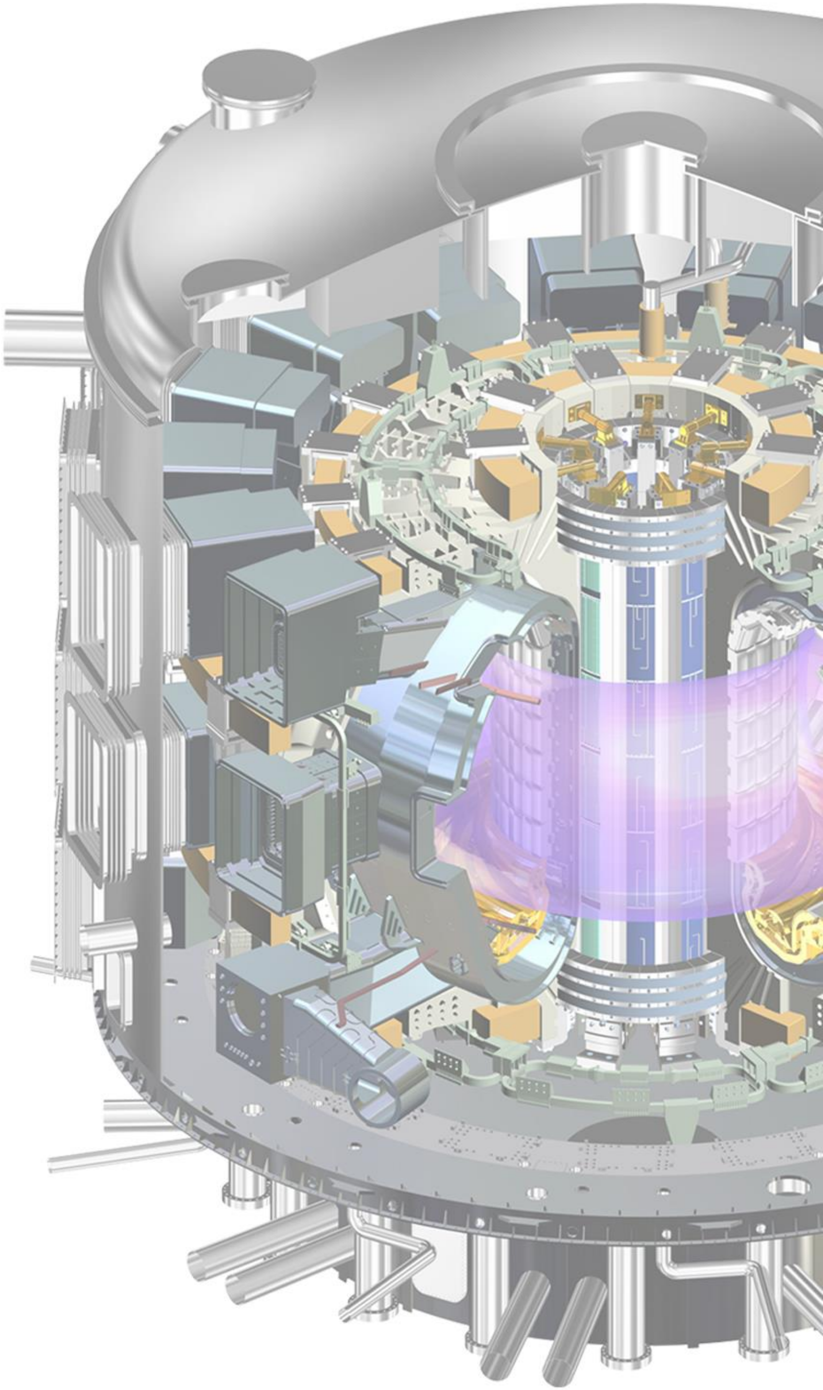
US ITER Vacuum Cryogenic System Overview



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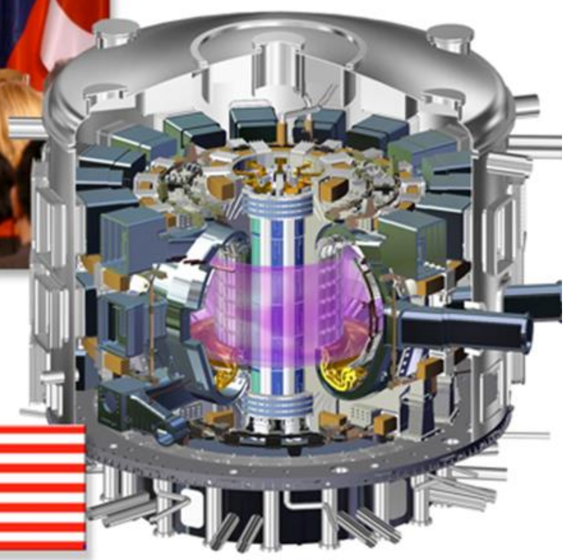
Overview of ITER

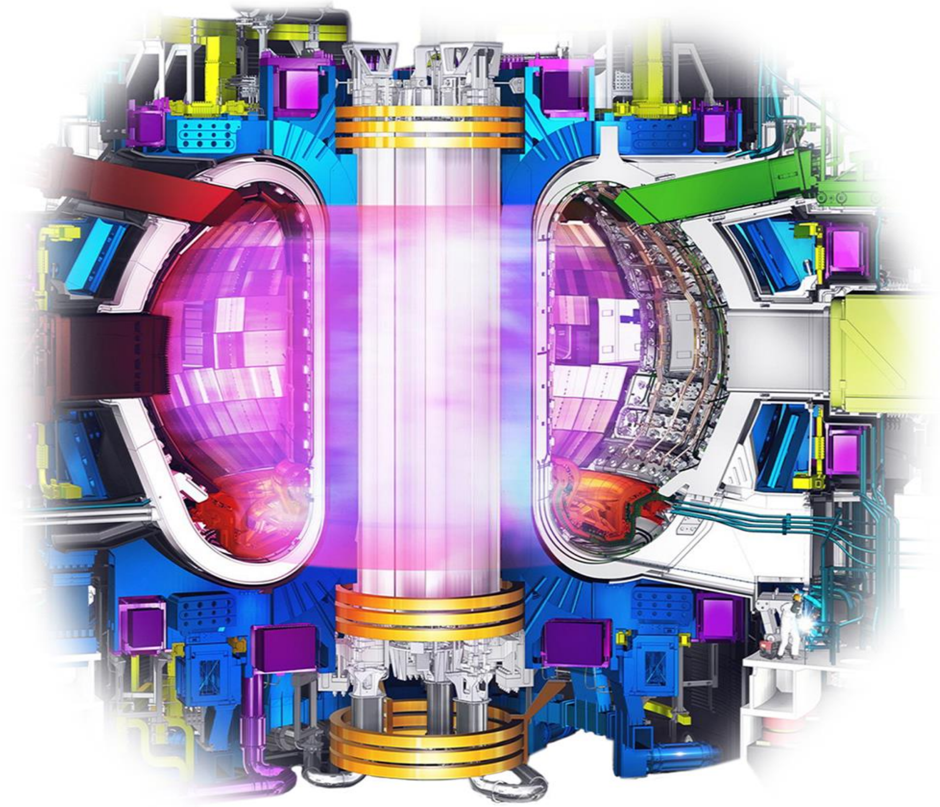
The signatories of the ITER Agreement with French Republic President Jacques Chirac in Paris on November 21, 2006.

China • European Union • India • Japan • South Korea • Russia • United States



Essential Elements of ITER

- Main ITER Elements: Confinement, Magnets, Vacuum, Heating, Cooling, and Fueling Systems
- The ITER vacuum system is at the frontier in its complexity, size, and importance
- The ITER vacuum system will be the FIRST vacuum system to ever be incorporated into a nuclear power plant
- ITER Vacuum Vessel and Cryostat are among the largest vacuum systems every built (1400m^3). Ultimate vacuum pressure 1*10^{-6} Pa
- The requirements mean that extraordinary measures must be taken to maintain quality and verify operational and safety cases.

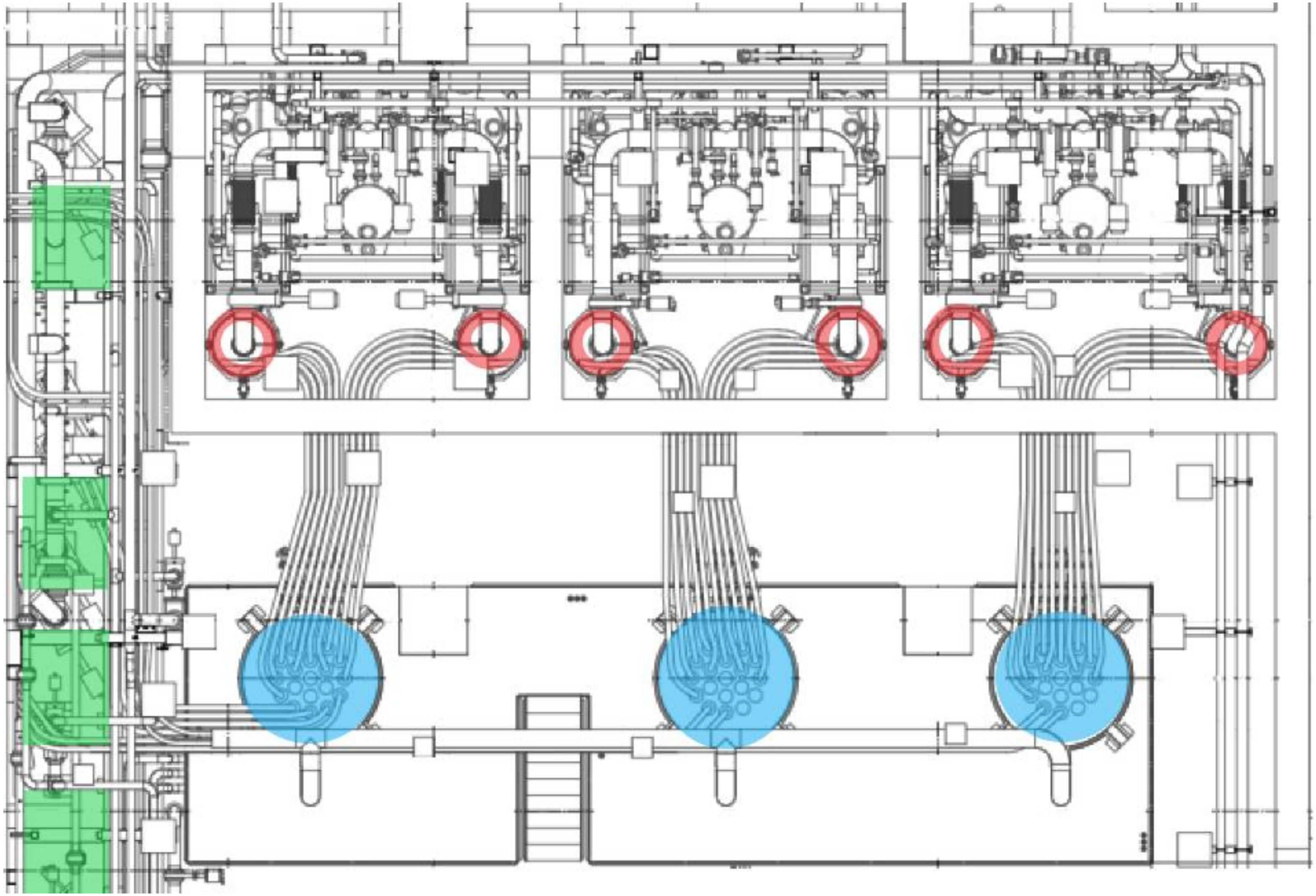


Roughing Pump System Cryogenic System

Roughing Pump System

- The Roughing Pump System (RPS) provides the RPS Cryogenic System, which is responsible for the regeneration of the Torus and Neutral Beam Cryogenic Pumps of the ITER tokamak.
  - Exhaust gas stream contains common gases and hydrogen isotopes (H2, D2, T2, and combinations).
  - Within the RPS Cryogenic System hydrogen isotopes are separated to allow for exhaust gas stream processing.
- Roughing and regeneration phases are made possible through RPS Cryogenic System Equipment: Cryogenic Viscous-flow Compressors (CVC), Condensable Vapor Devices (CVD), Cryogenic Distribution Boxes (CDB), and Cryogenic Transfer Lines (CTL).

Roughing Pump System

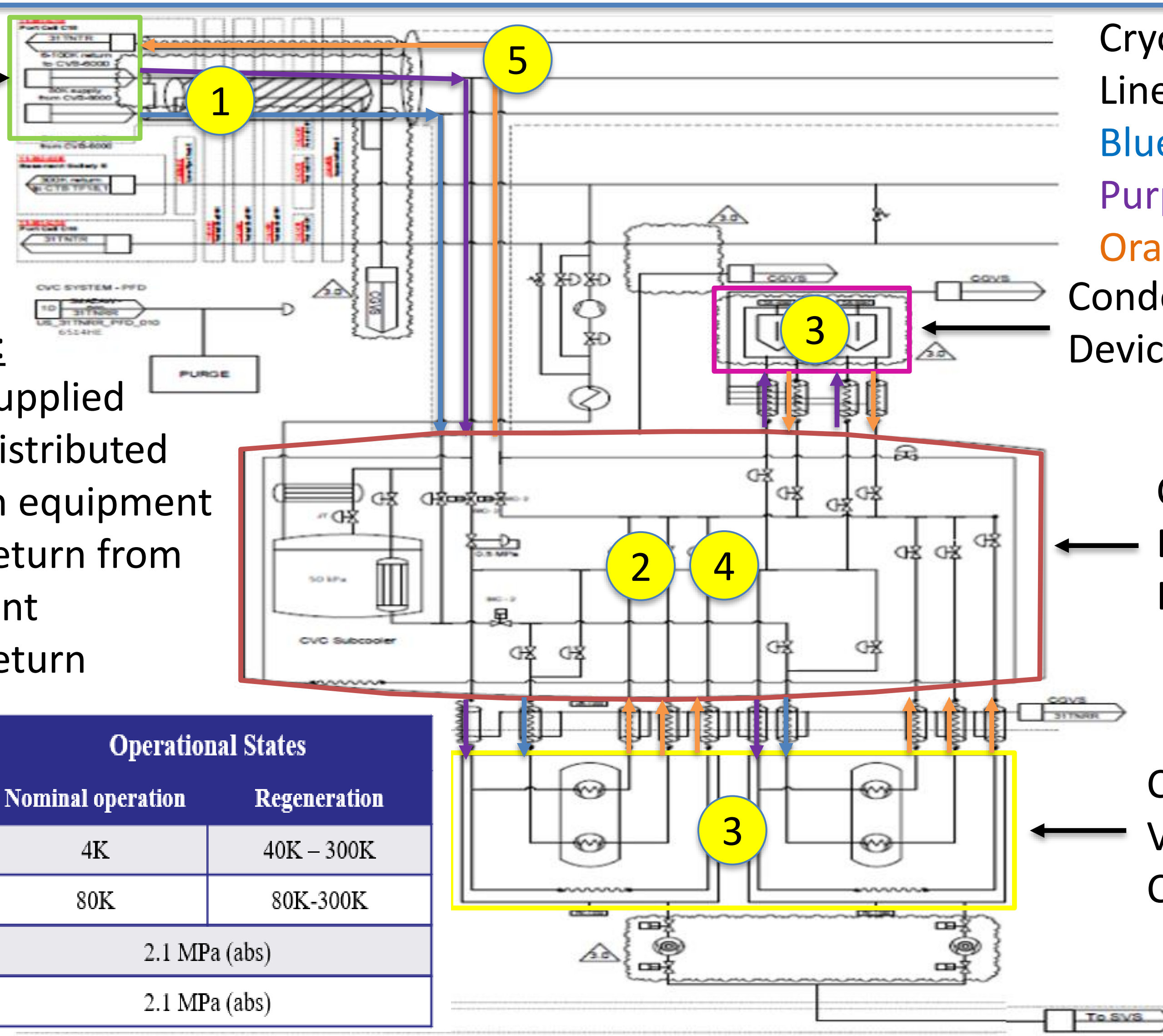


Cryogenic Distribution Boxes

Condensable Vapor Devices

Cryogenic Viscous-Flow Compressor

Process Flow Diagram - Cryogens



Supply and return of Cryogens

Cryogenic Transfer Lines:
Blue - SCHe Supply
Purple – GHe Supply
Orange – Return

Condensable Vapor Devices

Cryogenic Distribution Box

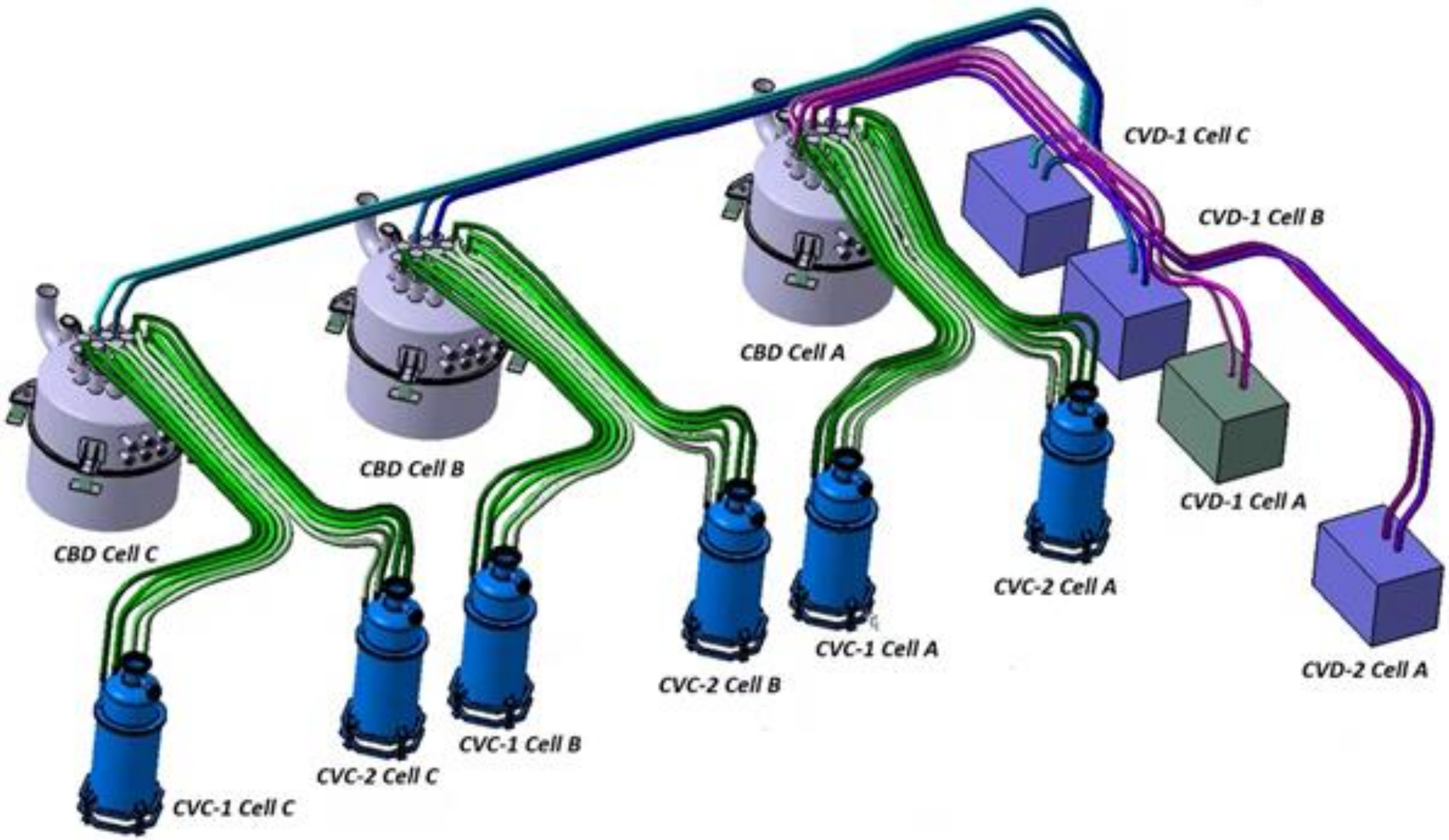
Cryogenic Viscous-Flow Compressors

Process Order:

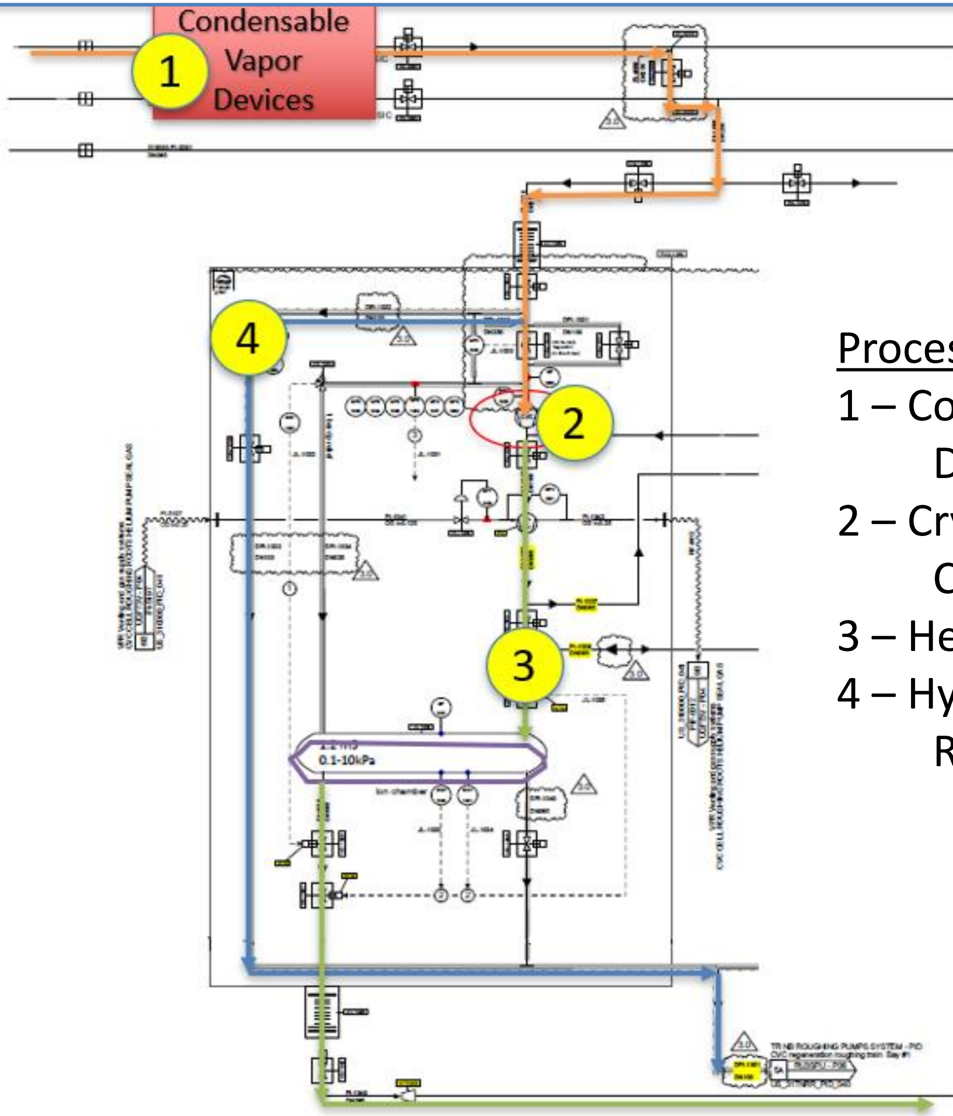
1 - Cryogens supplied
2 - Cryogens distributed
3 - Cryogens in equipment
4 - Cryogens return from equipment
5 - Cryogens return

	Operational States	
	Nominal operation	Regeneration
Temp. - 4K circuit	4K	40K – 300K
Temp. - 80K circuit	80K	80K-300K
Pres. in 4K circuit	2.1 MPa (abs)	
Pres. in 80K circuit	2.1 MPa (abs)	

Cryogenic Distribution



Process Flow Diagram – Process Gas



Process Order:

1 – Condensable Vapor Devices

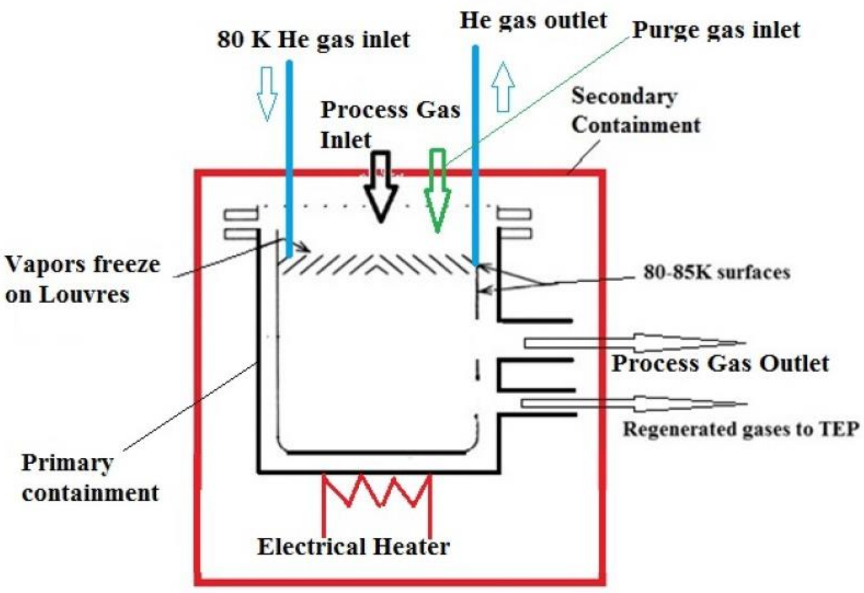
2 – Cryogenic Viscous-Flow Compressor

3 – Helium Flow

4 – Hydrogen Isotope Regeneration

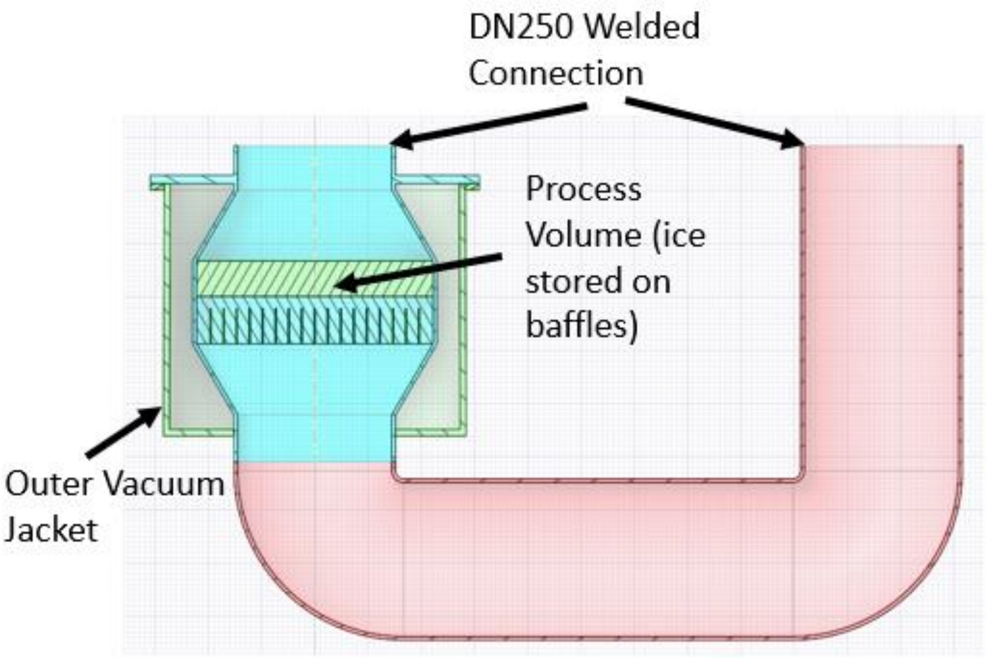
Condensable Vapor Devices (CVD)

- The CVDs receive 80K GHe from the distribution boxes
- The 80K freezes any tritiated water vapor in the process gas stream to the baffles before entering the Cryogenic Viscous-flow Compressor, protecting it from any water accumulation
- Regenerates once max amount of water is detected
- Heated using heaters and N2 gas to purge
- Regenerated gases are transferred to TEP through doubly contained lines with interspace monitoring

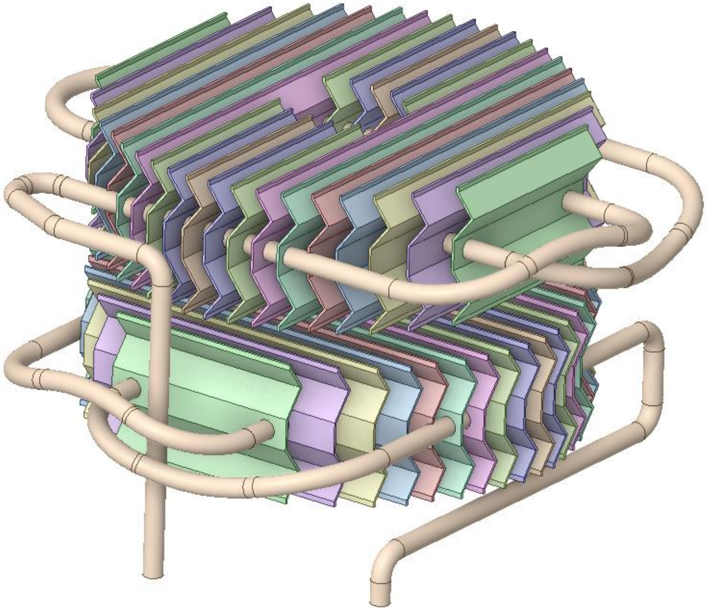


Process Flow of the Condensable Vapor Device

Condensable Vapor Devices (CVD)

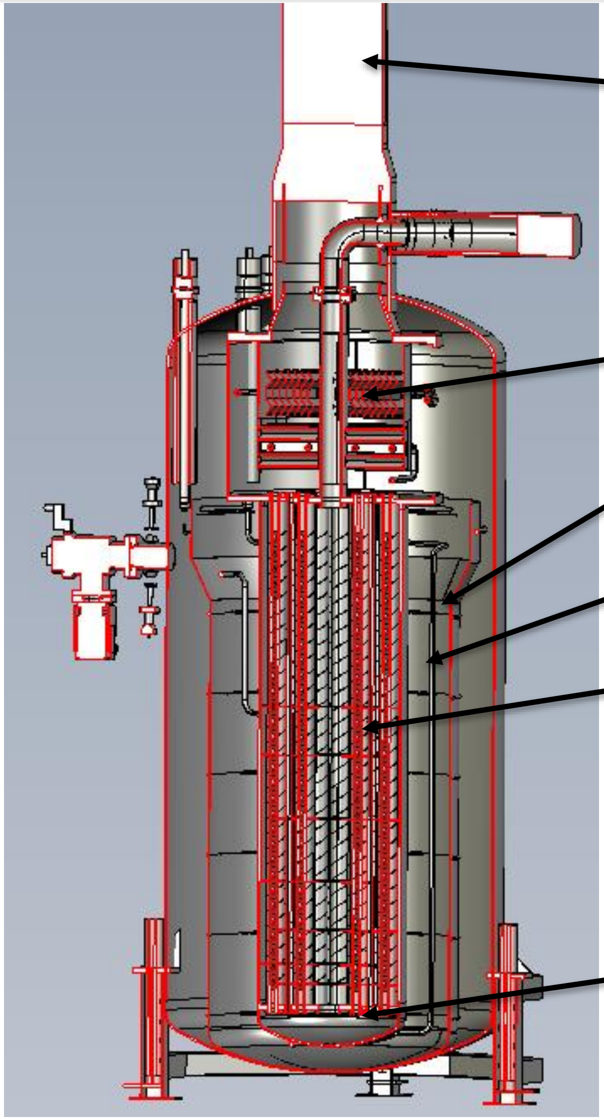


Preliminary Inline Condensable Vapor Device



Example of what 80K helium circuit and baffles could look like

Cryogenic Viscous-Flow Compressor (CVC)



Flow of up to 200 Pa·m³/s Hydrogen isotopes + He gas mixture at 293 K

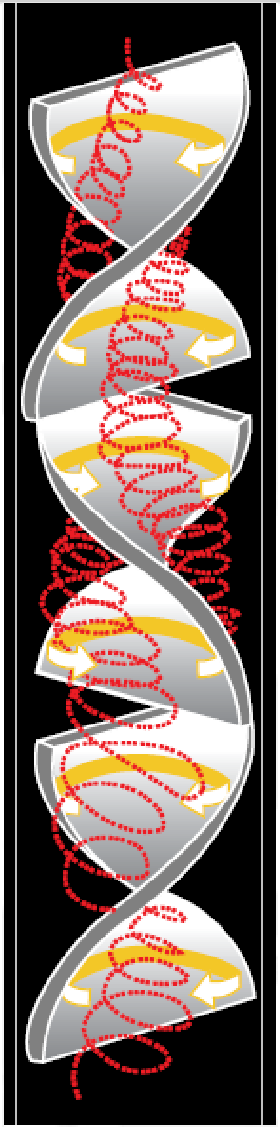
Baffles (precooler) and thermal shield cooled using 80K

Condenser cooled with ScHe (~4K)

Hydrogen isotopes freeze to the surfaces of the helical tubes.

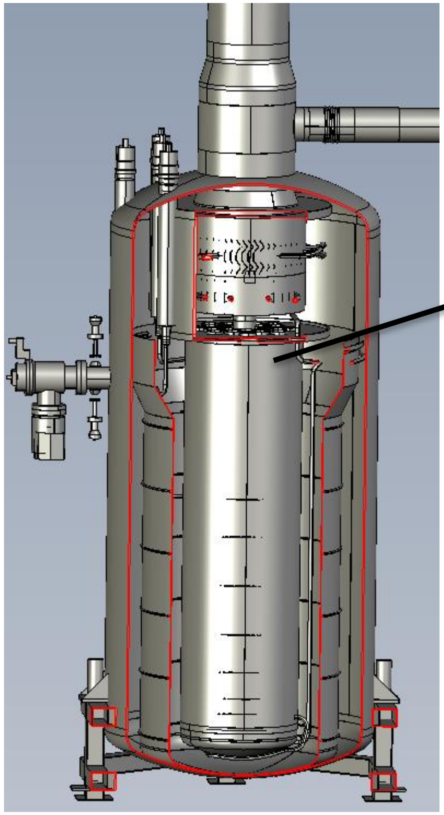
Helium gas becomes separated from the hydrogen isotopes, being first dragged by the viscous flow of the condensing stream and then pumped by a mechanical exhaust pump.

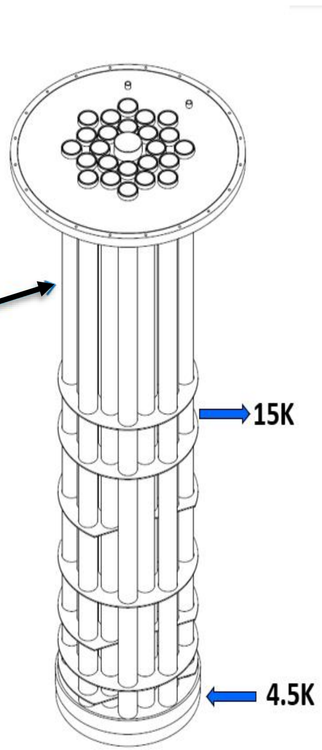
Cryogenic Viscous-Flow Compressor (CVC)



The condenser has a heat exchanger design using 24 tubes with a length of 1.4 m and a diameter of 50 mm.

The helical tubes direct the flow radially towards the cold tube walls and back to the center. This avoids radial gradients in the flow and is required for the complete phase change of hydrogen and dragging the helium.





Conclusion

The Cryogenic Vacuum System is a complex system with first of its kind equipment.

- Regeneration of the Torus and Neutral Beam Cryopumps is completed through the Cryogenic Vacuum System allowing for sustained vacuum during plasma operations.
- The Cryogenic Vacuum System separates Helium from Hydrogen Isotopes for use later in the ITER system.

In total, the RPS Cryogenic System will allow ITER to engage in the critical science of developing sustainable burning plasma operations to facilitate the design and construction of commercial fusion power plants.

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QUESTIONS?

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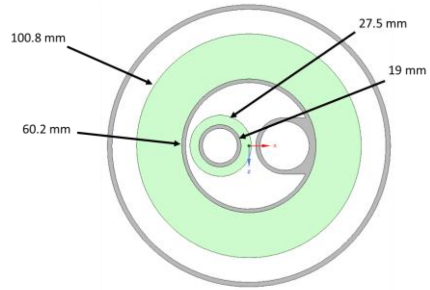
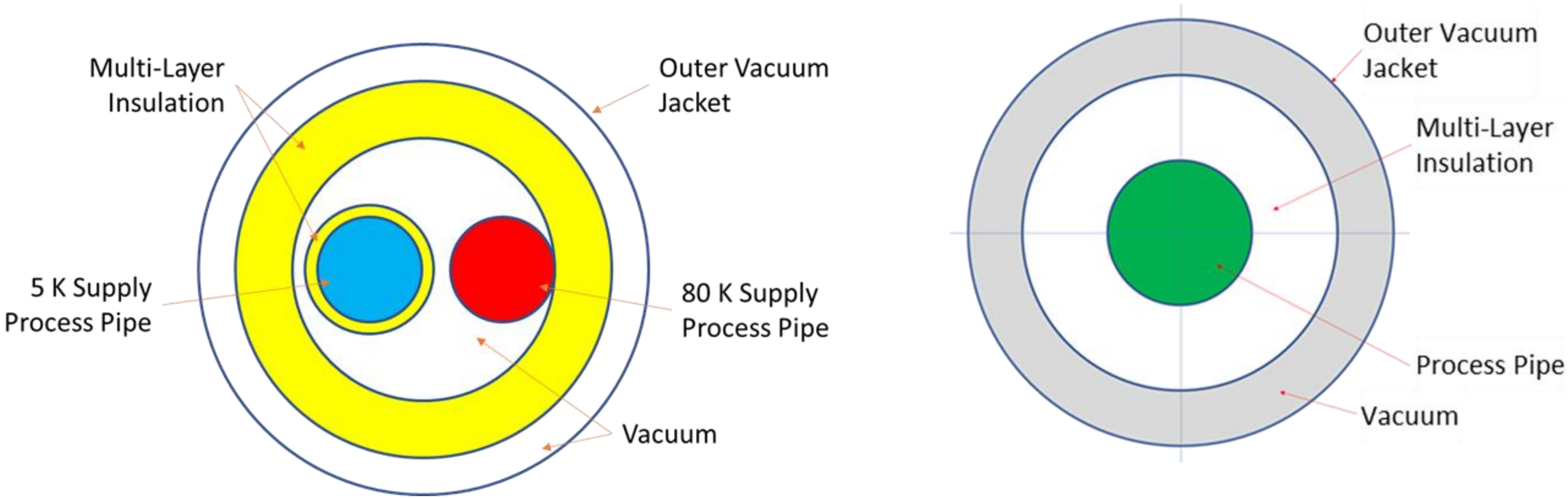
Cryogenic Transfer Lines





Cross-Sections of Double-Flow Rigid CTL *(left)* and Single-Flow Flexible CTL *(right)*

Environment

- All equipment is located in the Vacuum Pumping Room (VPR), except for the Cryogenic Transfer Lines which run from Port Cell 18 to the VPR.

Condition	Minimum	Maximum	CTLs
Temperature, ˚C	18	35	18 - 35
Pressure, Pa(g)	-50	-50	-50
Humidity	0%	60%	20 -60% RH
Magnetic Field, mT	~5mT	~15mT	≤130 (≤16 JC)
Radiation (silicon dose)	N/A	N/A	≤ 1 MGy@4700 h