Status of the ITER Cryodistribution

H.-S. Chang[1], H. Vaghela[2], P. Patel[2], A. Rizzato[1], M. Cursan[1], D. Henry[1], A. Forgeas[1], D. Grillot[1], B. Sarkar[1], S. Muralidhara[2], J. Das[2], V. Shukla[2], E. Adler[3]

[1]*ITER Organization, Route de Vinon sur Verdon, 13115 St Paul Lez Durance, France*
[2]*ITER-India Institute for Plasma Research, Block-A Sangath Skyz, 380 005 Ahmedabad, India*
[3]*Linde Kryotechnik AG, Dättlikonerstrasse 5, 8422 Pfungen, Switzerland*

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Abstract

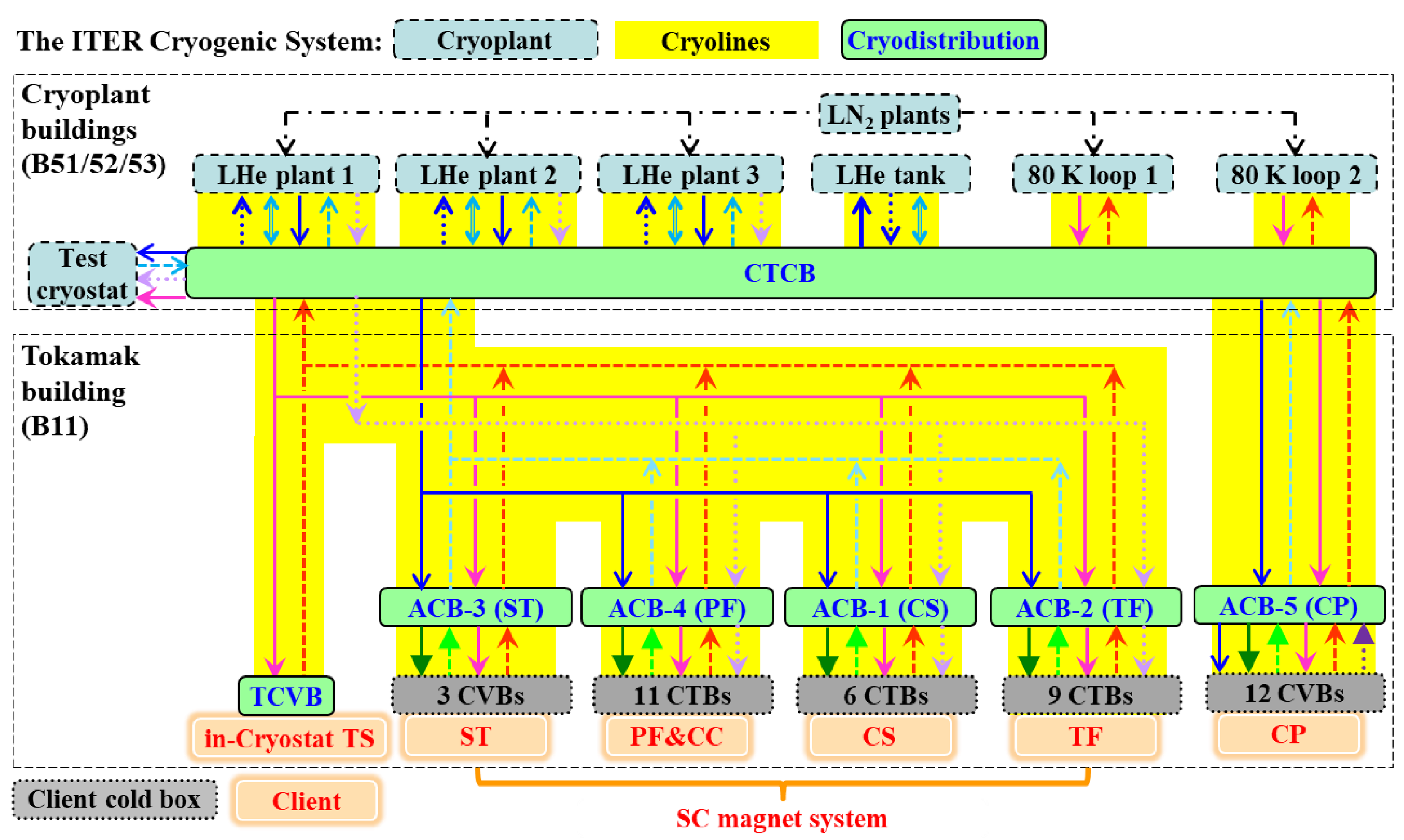
Since the conceptual design of the ITER Cryodistribution (CD) many modifications and changes have been applied due to both system optimization and improved knowledge of the clients' requirements. A summary of present design status and component configuration of the CD with all the changes implemented which aim at process optimization and simplification as well as operational reliability, stability and flexibility will is presented.

LHe	Liquid Helium	**CTCB**	Cryoplant Termination Cold Box	**CCL**	Cold CircuLator	**CS**	Central Solenoid (coil)
SHe	Supercritical Helium	**ACB**	Auxiliary Cold Box	**CCP**	Cold ComPressor	**TF**	Toroidal Field (coil)
GHe	Gaseous Helium	**TCVB**	Thermal Shield Cold Valve Box	**HX**	Heat eXchanger	**ST**	(magnet) STructure
LN_2	Liquid Nitrogen	**TS**	Thermal Shield	**PS**	Phase Separator	**PF&CC**	Poloidal Field & Correction Coils

LHe (line A) from LHe tank	50 K GHe to current leads (line H)	LN_2
GHe (line B), return of flash/tank pressurization		SHe downstream CCL (line CC)
J-T stream SHe (line C)	80 K GHe to TS (line E)	SHe upstream CCL (line CD)
Evaporated GHe (line D)	100 K GHe from TS (line F)	Cold recovery from CP (line CR)

Valve 100 % open	Temperature sensor	80 K thermal shield	Heater unit off
Valve control opened	Pressure sensor	Coriolis mass flow meter	Heater unit on/operating
Valve closed	Mass flow meter	Filter unit	Connection to test cryostat
Cold circulator	CRM warm-up port	SHe/LHe HX	LHe level sensor
Cold compressor	CRM thermal shield	SHe/GHe HX	ΔP sensor

1. Schematic Overview of the ITER Cryogenic System



2. Status of the Cryoplant Termination Cold Box (CTCB)

Valves at CTCB interfaces with Cryolines are for (dis)connection with Cryoplant and ACBs/TSCS are fully open or closed without active control during operation and managed by the Cryogenic System Master Controller (MC).

Active controls managed by CTCB are:

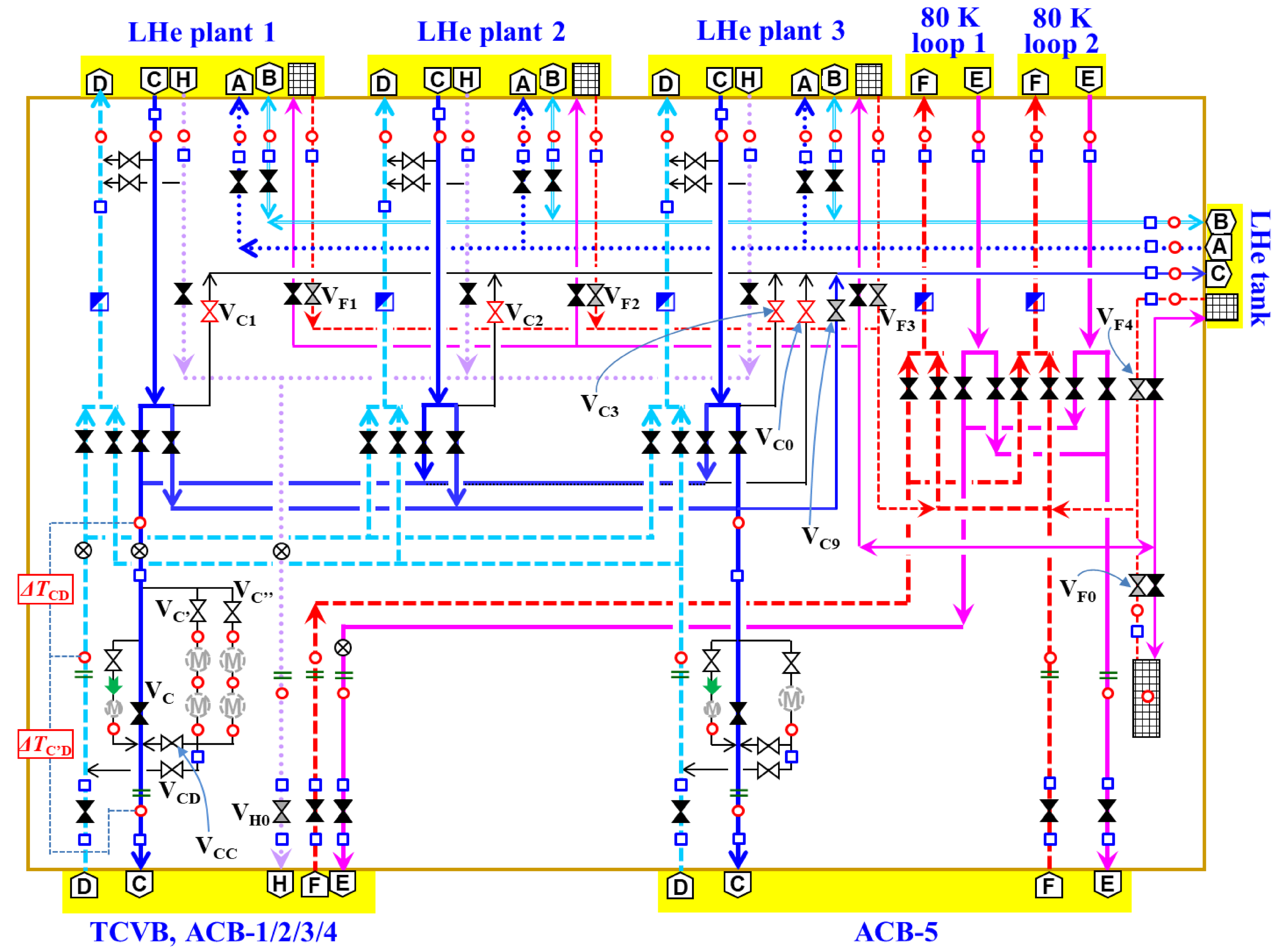
i) SHe downstream last turbine T4 of each LHe plant is collected in line C manifold and then expanded to the LHe tank via V_{C0} (or V_{C9}), while keeping P close to 5 bar (same for line H downstream first turbine T1 of each LHe plant using V_{H0});

ii) In case only one LHe plant has to be operated and connection to the ACBs is not allowed (*e.g.*: liquefaction of GHe into LHe tank for inventory storage during Tokamak maintenance) P of line C can be adjusted by the valves V_{CN} (N=1–3);

iii) During warm-up, SC magnets (total mass of ~10,000 tons) act as cold source. For thermal balance inside LHe plants (*i.e.* keep ΔT_{CD} below 20 K), V_C is closed, $V_{C'}/V_{C''}/V_{CC}$ opened and heaters are operated. When heater power is at maximum and ΔT_{CD} close to limit value, V_{CD} is opened to decrease ΔT_{CD};

iv) The TS T of the LHe-plant/tank-interfacing Cryolines and the CTCB itself is controlled by maintaining ΔT between the supply and return GHe within 20 K by using V_{FN} (N=0–4) (applicable for all operation modes like cool-down /warm-up of the TS's);

v) Coriolis flow meter with a valve upstream, heater and T sensor downstream are acceptance plan and performance measurement of the ITER Cryoline system.



3. Optimizations of the Auxiliary Cold Box (ACB) Configuration

Due to the additional nuclear load during the D-T plasma phase, cooling power to maintain the thermal stability of the SC magnets can be beyond the capacity of the Cryoplant.

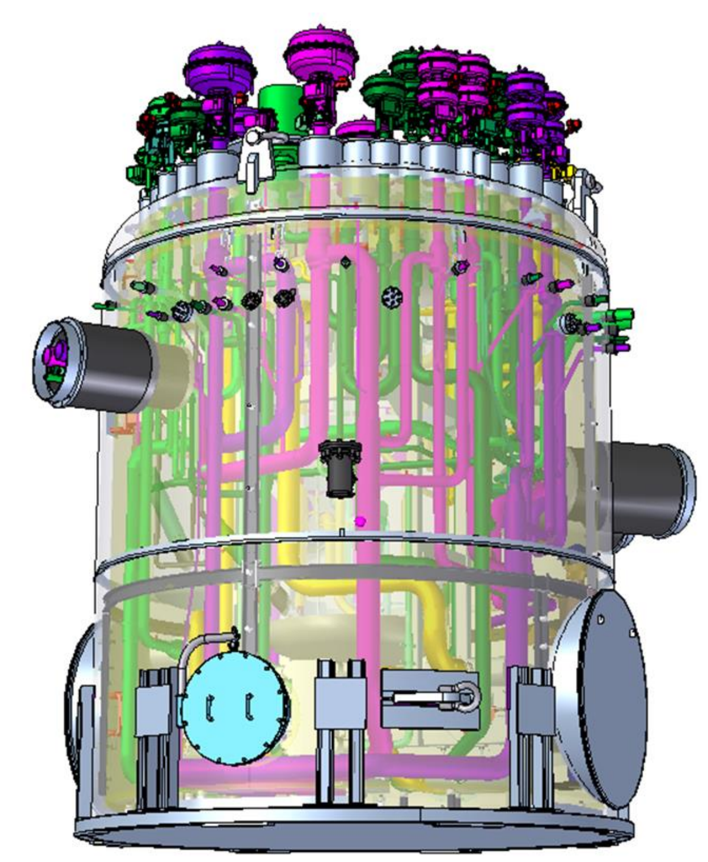
To allocate more cooling power to the magnet system, each ACB is equipped with own CCP (removal of Cold Compressor Box) and double PS which allowed standardization of ACB configuration:

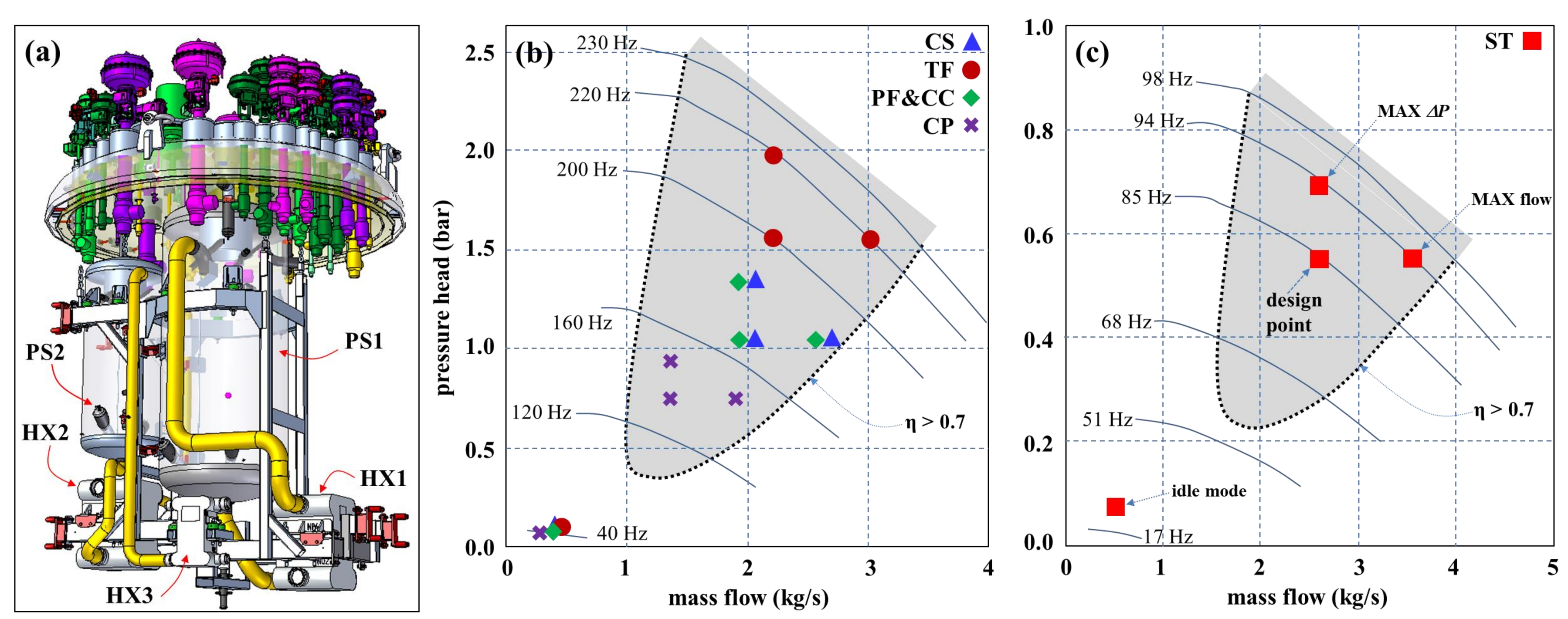
i) Outer vacuum jacket (OVJ) of the ACBs: same physical dimension;

ii) PS1/PS2 and HX1/HX2/HX3: same physical dimensions and specifications for all ACBs;

iii) CCL: Same type for all five except different cold casing and impeller for ACB-3 (ST) [6];

iv) CCP: Same warm part for all five, for cold parts (cold casing and impeller) three different types for ACB-1/4 (CS/PF&CC), ACB-2/3 (TF/ST) and ACB-5 (CP).





Valves at ACB interfaces with Cryolines are for (dis)connection with CTCB and client cold boxes are managed by the MC.

The ACB control system has to manage the automatic switching (when requested by the MC) among operation modes

Active process controls to be managed by the ACB control system are:

i) Keep the LHe level of PS1/PS2 within acceptable range using V_{JT1}/V_{JT2};

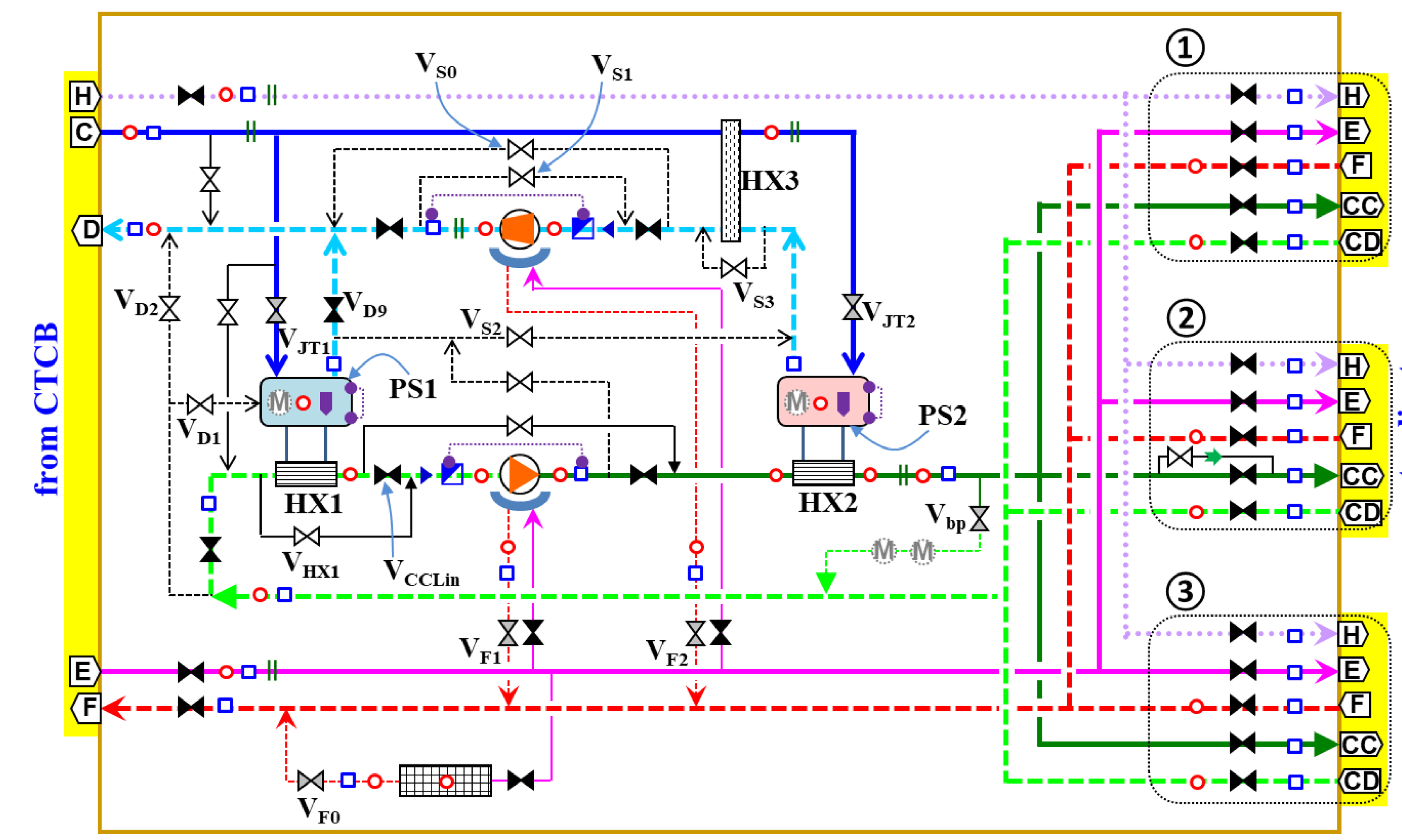
ii) Rotational speed control of CCP to maintain the vapor pressure of PS2 within allowed range;

iii) Surge protection of CCP using V_{S1} (warm mass flow feed) and V_{S2}/V_{S3} (cold mass flow feed);

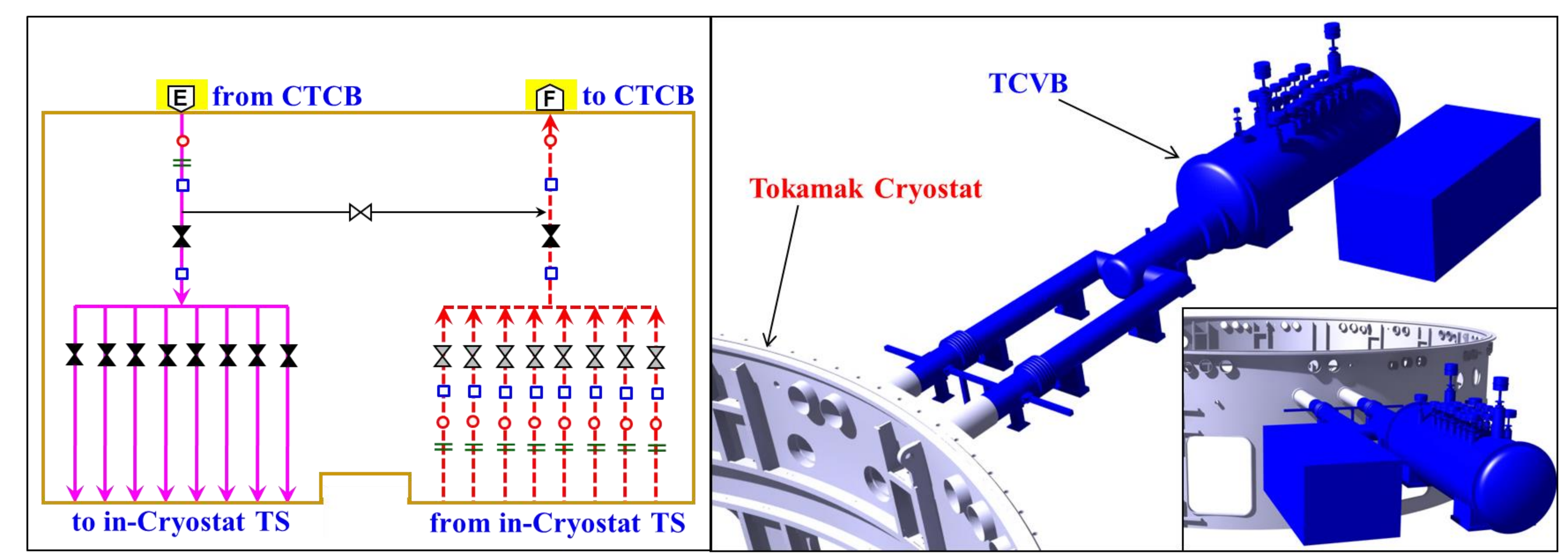
iv) Surge protection of CCL (operated at constant rotational speed) by using V_{bp};

v) As in case of CTCB, maintain the ΔT between the supply and return GHe within 20 K by controlling the V_{FN} (N=0–2);

vi) In case of ACB-4, since it is foreseen that the SHe T upstream HX1 can be lower than the LHe T in PS1, to prevent cooling of PS1 (normally to be evaporated for heat exchange), HX1 is by-passed by opening V_{HX1} and closing V_{CCLin}.



4. Status of the Thermal Shield Cold Valve Box (TCVB)



Conclusion

- **The ITER CD has been optimized with respect to its interfacing system process as well as clients' requirement changes and is in the final design (ACBs/TCVB) and manufacturing (CTCB) phase at Linde Kryotechnik.**
- **One CCL (TF) manufactured and tested, others in manufacturing phase at IHI**
- **The on-site delivery starts with the CTCB on May 2018 to match the commissioning of the three LHe plants' parallel operation. ACBs and TCVB will be delivered until late 2020, installed and commissioned to be ready for the ITER first plasma in 2025**

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization and its members