Design Realization Towards the Qualification Test of ITER Cold Circulator

*R. Bhattacharya, B. Sarkar, **H. Vaghela**, P. Patel, J. Das, Srinivasa M., V. Shukla*

ITER-India, Institute for Plasma Research, Near Indira Bridge, Bhat, Gandhinagar 382 428, INDIA

C1PoF-02 [C2]

Background

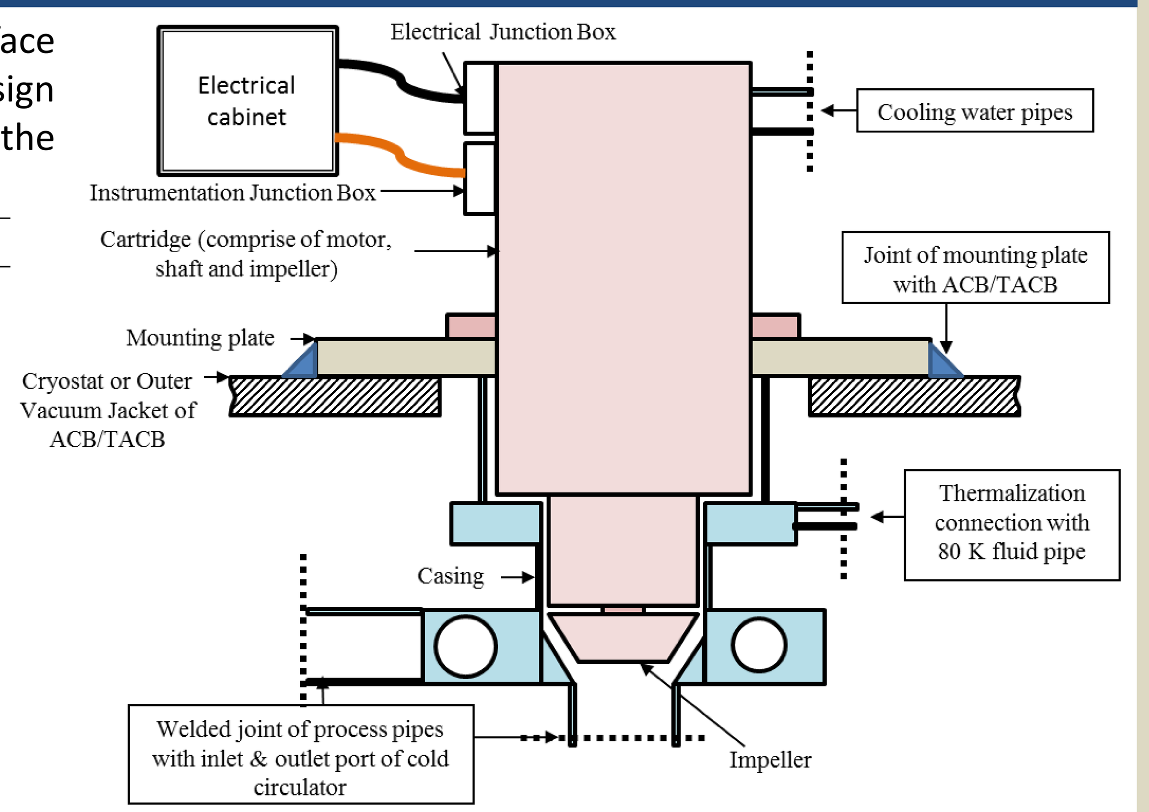
- The main function of the cold circulator (CC) is to establish and maintain forced-flow supercritical helium (SHe) flow at flow-path of the toroidal field (TF) superconducting magnet of ITER.
- The major challenging tasks of CC are to operate at vigorous operating regime of superconducting magnet having an isentropic efficiency of 70 %. Two cold circulators for TF superconducting magnet have been designed, manufactured by industrial partners in order to perform the qualification test of cold circulator prior to the final design of ITER cryo-distribution system.
- Interface management has been identified as the high-risk area for the project involving three industrial partners; M/s. IHI Corporation, Japan for Cold Circulator-1 (CC-1), M/s. Barber-Nichols Inc., USA for Cold Circulator-2 (CC-2) and M/s. Taiyo-Nippon Sanso Corporation, Japan for TACB as well as the cryogenic test facility at JAEA-Naka, Japan.

Design Interfaces of Cold Circulators

The methodology of interface management and control has been implemented by (i) identifying all the interface points, (ii) defining design responsibilities of the interface points, (iii) updating the counter-interface design suiting the original interface and (iv) verifying the integrated system by suitable analysis, which reduces the design iterations.

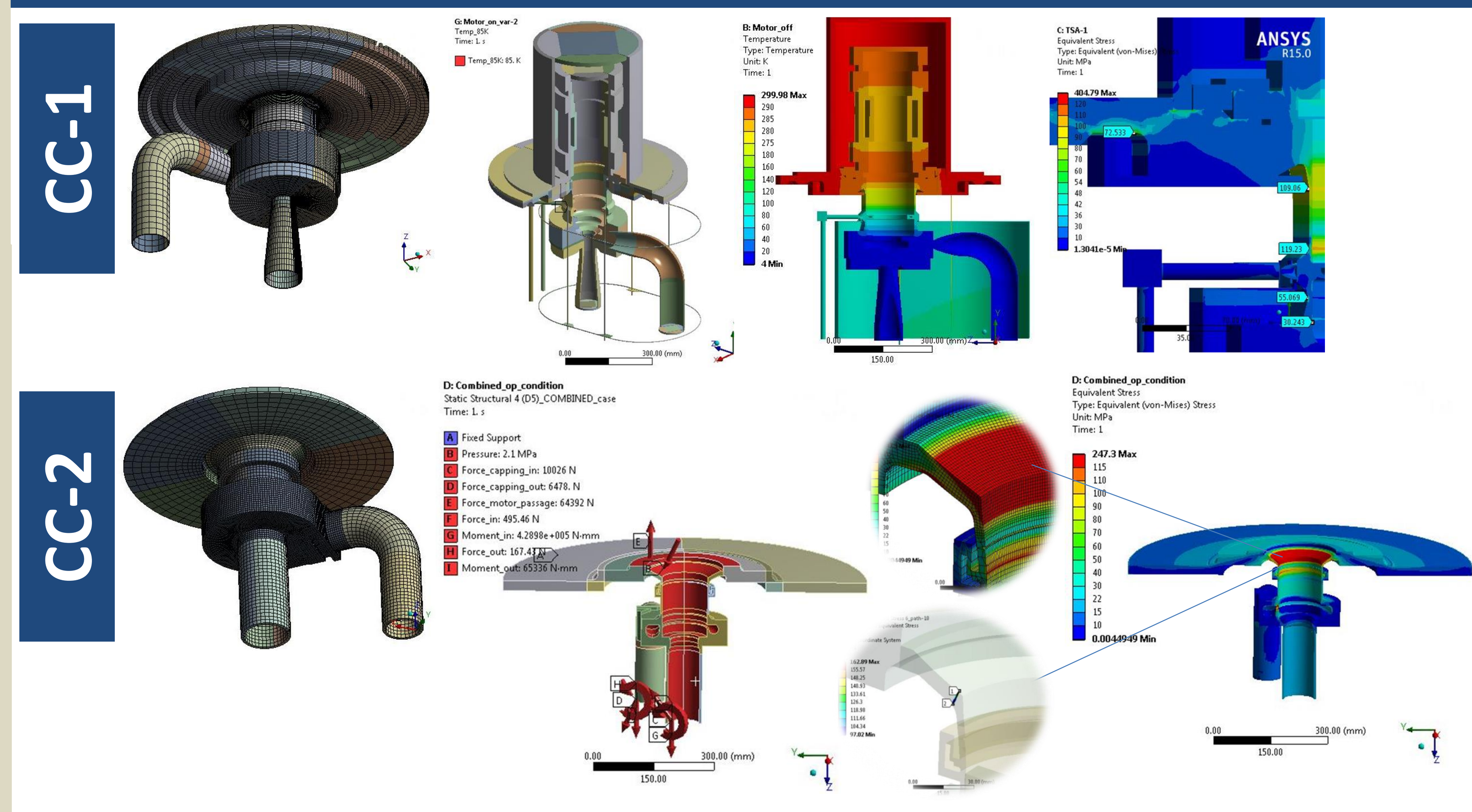
List of Interfaces of cold circulator

Interfaces	Interface Point
Physical Interfaces	▪ SHe suction and discharge nozzles, ▪ 80 K thermalization ▪ Mounting plate/flange of the cold casing ▪ Shield for magnetic field (as applicable) ▪ Interface with utilities (cooling water nozzles, electrical power)
Instrumentation and control Interfaces (I&C)	▪ I&C signal interface PLC of TACB and cold circulators ▪ Logical interfaces between the cold circulator and TACB ▪ Cable tray ▪ Cabinet interface at the cryogenic test facility
Functional interfaces at facility	▪ Functional interface must satisfy all the operating conditions during the qualification test.

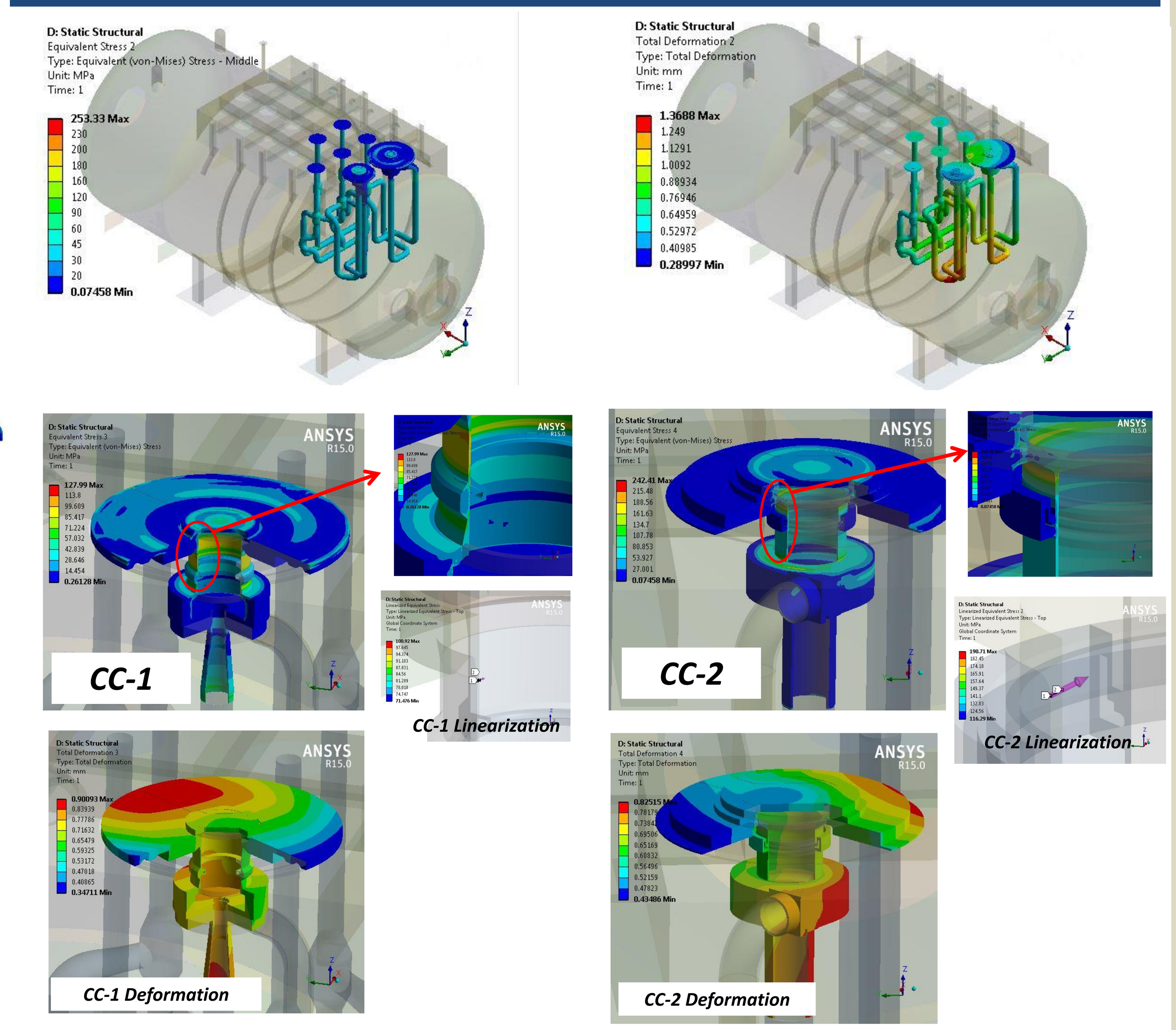


Schematic diagram of CC with interfaces

Thermo-mechanical Analysis



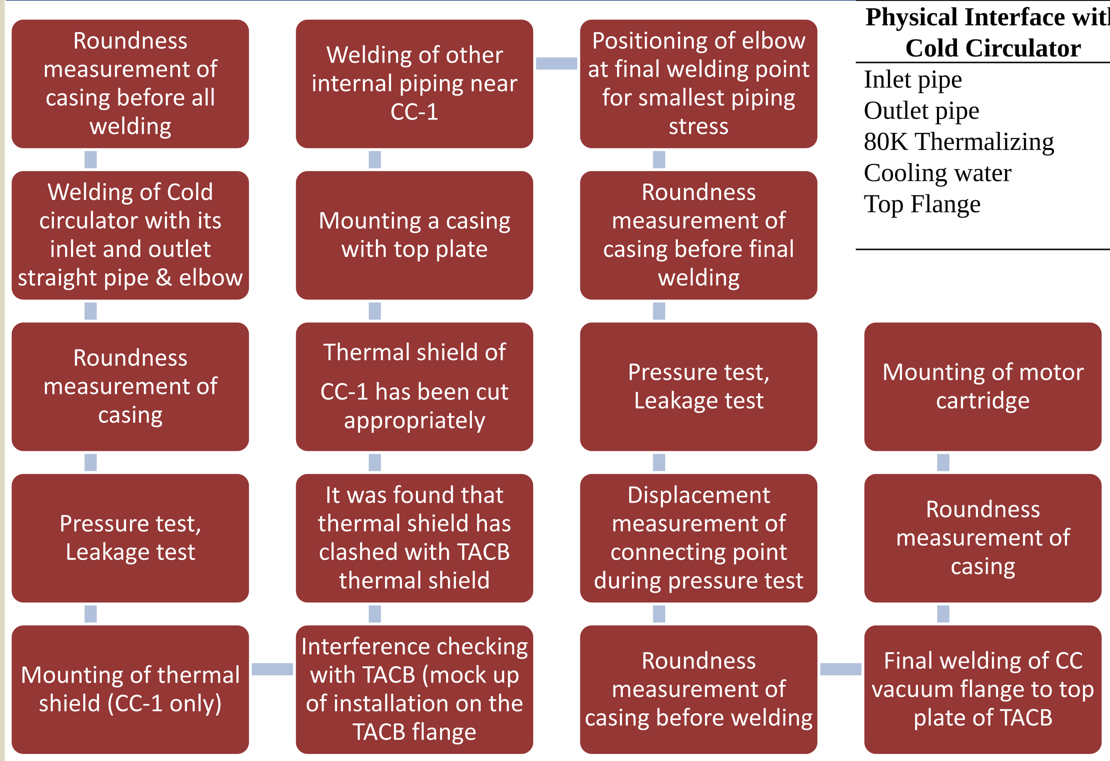
Pressure Test Condition



Interface loads for cold circulators

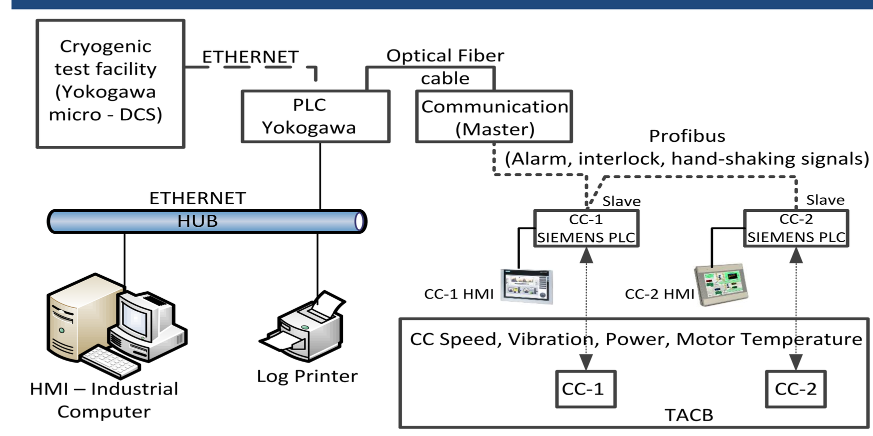
Description		Unit	Nozzle Loading on CC-1 Inlet	Nozzle Loading on CC-1 Outlet	CC-1	Nozzle Loading on CC-2 Inlet	Nozzle Loading on CC-2 Outlet	CC-2
Design conditions [2.0 MPa & 4.15 K]	Forces-X direction	[N]	-196.75	-377.53	Passed	-116.67	-28.99	Passed
	Forces-Y direction	[N]	202.79	325.9		289.21	61.52	
	Forces-Z direction	[N]	189	-7		-385	153	
	Moment-X direction	[Nm]	316.12	315.68		357.8	57.98	
	Moment-Y direction	[Nm]	204.45	361.23		231.93	29.7	
	Moment-Z direction	[Nm]	73	4		47	-5	

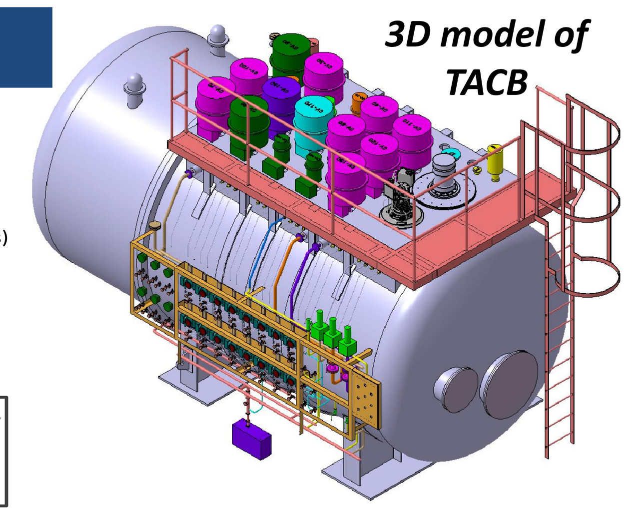
Installation Methodology



Physical Interface with Cold Circulator	TACB DN	TACB OD [mm]	TACB T [mm]	CC-1 DN	CC-1 OD [mm]	CC-1 T [mm]	CC-2 DN	CC-2 OD [mm]	CC-2 T [mm]	Type of interface connection
Inlet pipe	80	89.1	3	80	89.1	3	80	88.9	5.49	TIG welding
Outlet pipe	65	76.3	3	80	89.1	3	65	73.0	5.16	TIG welding
80K Thermalizing	8	13.8	1.65	8	13.8	1.65	8	13.8	1.65	TIG welding
Cooling water	Swagelok SS-6-TA-7-6RT (3/8")			SS600-1-6W (3/8") Swagelok fitting			SS-600-1-6ST (3/8")			Swagelok fitting
Top Flange	Ø700 for CC-1 Ø400 for CC-2			Ø692			Ø482.6			TIG welding

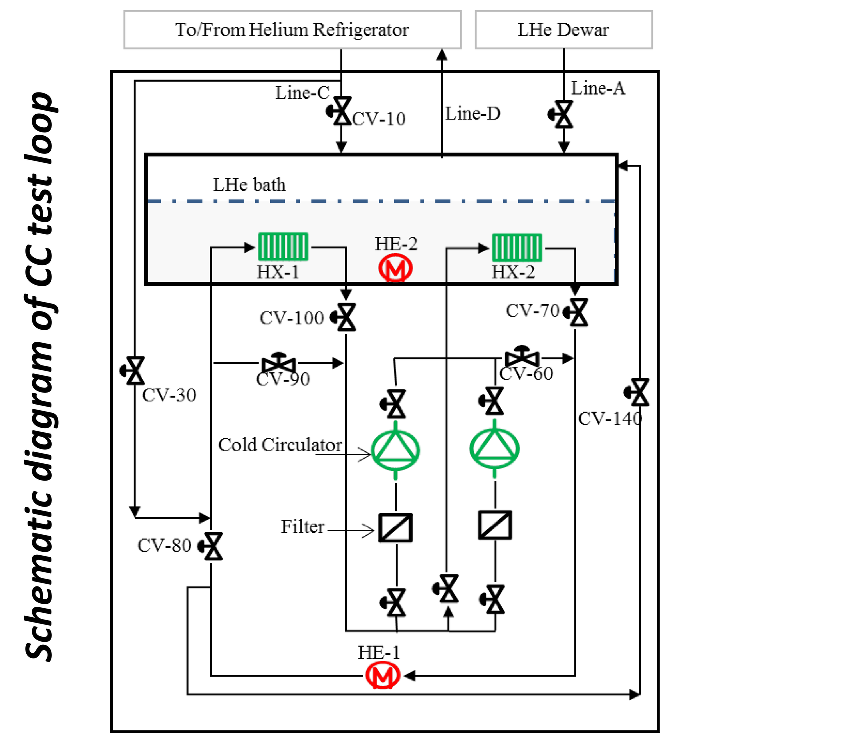
Control Methodology





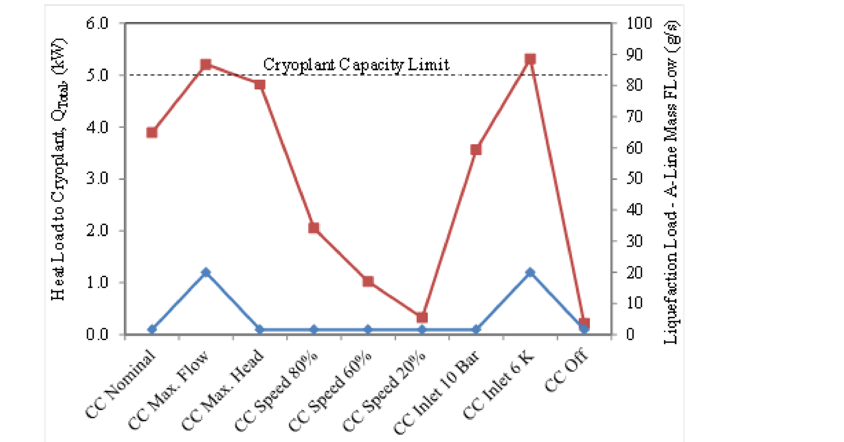
3D model of TACB

Functional Interface



Schematic diagram of CC test loop

- Stable operation during the qualification test for CC has been ensured by analysing the functional interface with the cryogenic test facility at JAEA-Naka facility with capacity as ~ 5.0 kW@4.5K or 800 l/h.
- Functional interfaces evaluated for (i) Nominal, (ii) Maximum mass flow at 110 % speed, (iii) Maximum pressure head at 110 % speed, (iv) Different speeds at 80 %, 60% and 20%, (v) Cold Circulator inlet at 10 Bar, (vi) Cold Circulator inlet at 6 K and (vii) cold circulator OFF.



Realization

Manufacturing of TACB near completion

Cold Circulator-2

Cold Circulator-1

- Manufacturing of TACB is near completion and will be ready for Japanese regulatory inspection for the completer system including both cold circulators

Factory Acceptance Test

- Factory acceptance test (FAT) of cold circulators from both suppliers has been completed successfully.
- Verification of all the interfaces has been performed satisfactorily. The test results are summarized in Table below, which have been performed under no-load condition.

Summary of FAT results

	CC-1	CC-2
Speed at Design Point (rpm)	12000	8000
Mock-up Cartridge Replacement time (mm:ss)	60:00	55:35
Electrical input power to motor at 100% speed (kW)	0.33	2.1
Electrical input power to motor at 110% speed (kW)	0.43	2.2
Vibration Upper bearing at 100% speed (Resultant)	1.0 μm	1.36 mm/s
Vibration Lower bearing at 100% speed (Resultant)	1.0 μm	0.77 mm/s
Vibration Upper bearing at 110% speed (Resultant)	1.0 μm	1.19 mm/s
Vibration Lower bearing at 110% speed (Resultant)	1.0 μm	0.54 mm/s
Acoustic Noise at 1 m distance, 100% speed (dB)	62.5	64.2
Acoustic Noise at 1 m distance, 110% speed (dB)	62.5	65.6

Conclusion

- Designs of two cold circulators along with TACB have been completed with supporting analysis.
- Integrated analysis has been performed in order to obtain a safe interfacing design condition for physical interfacing points.
- Results show that stresses and deflections are within the allowable limit as per the selected material and construction codes and standards.
- Functional interface has been evaluated considering all modes of operation for the cold circulators suitable to the cryogenic test facility.
- Factory acceptance tests for both the cold circulators have been successfully completed and ready for the final qualification test.

Acknowledgement

Authors would like to thank the colleagues from ITER-India, ITER Organization in France for their contribution to ITER Cold circulator and TACB project with specific gratitude to the Project Director, ITER-India and Director, IPR. Special thank is extended to the Industrial partners namely M/s Barber Nichols Inc. (USA), M/s IHI (Japan), M/s Taiyo Nippon Sanso (Japan)

References

1. R. Bhattacharya, B. Sarkar, H. Vaghela, P. Patel, Srinivasa M., H.-S. Chang, T. Isono, Katsumi Kawano, Minoru Sato, M. Chalifour, "Control methodology and test modes during the qualification test of ITER Cold Circulator", in press Physics Procedia (2014)
2. Chang H.-S., Monneret E., Forgeas A., Maekawa R., Bonneton M., Fauve E., Chalifour M., Serio L., Park D.-S., Joo J.-J., Moon K.-M., Park Y.-M., "Design Specification of the ITER Cryodistribution Cold Rotating Machines", Proceedings of ICEC 24-ICMC 2012, pp: 599-602
3. K. Hamada et al, "Final Design of a Cryogenic System for the ITER CS Model Coil", Cryogenics Vol 34, 1994, 65 – 68
4. Sarkar B. et al, "Adaptability of Optimization Concept in the Context of Cryogenic Distribution for Superconducting Magnets of Fusion Machine", Advances in Cryogenic Engineering 57, 1951- 1958 (2012)
5. H. Vaghela, B. Sarkar, R. Bhattacharya, H. Kapoor, M. Chalifour, H.-S. Chang, L. Serio, "Performance Evaluation Approach for the Supercritical Helium Cold Circulators of ITER", Advances in Cryogenic Engineering, AIP Conf. Proc. 1573, 872-879 (2014); doi: 10.1063/1.4860795

Presented at Cryogenic Engineering Conference and International Cryogenic Materials Conference, 2015 June 28-July 2, Tucson, Arizona; Program I.D. number: C1PoF-02 [C2]