Value Engineering in System of Cryoline and Cryodistribution for ITER: In-kind Contribution from INDIA

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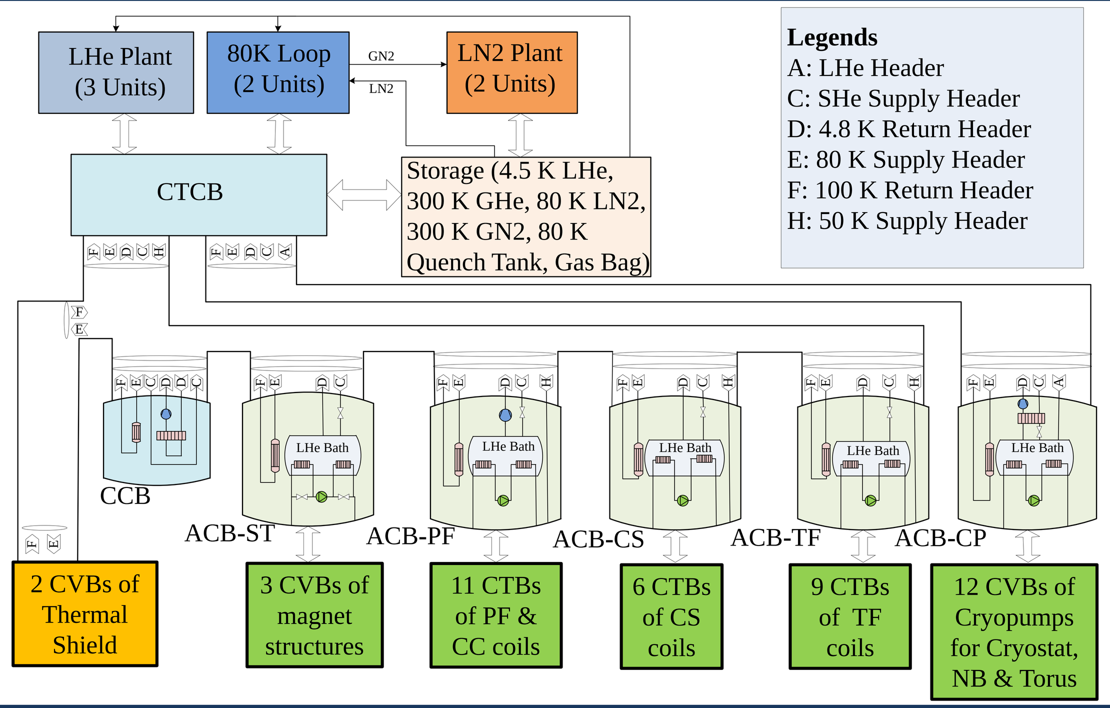
C1PoD-08 [C30]

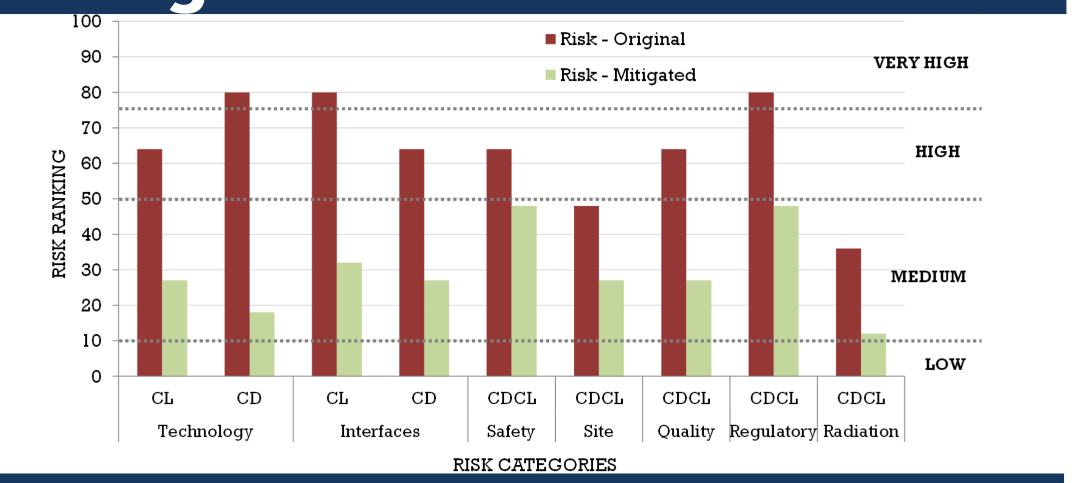
INTRODUCTION

- The ITER cryogenic system consists of three main subsystems; the Cryoplant, the Cryo-distribution (CD), as well as the system of Cryoline (CL) and Warmlines (WL) systems. The CD and CL systems are part of the in-kind supply from India.
- The cryoplants provide the required cooling power for the clients, namely, the superconducting magnet system, Cryo-pumps and thermal shield for the main cryostat.
- The CD system controls and manipulates the different operational scenario of ITER and the CL system establishes the two way communication of the required flow of cryogen as per the ITER cryogenic process with the structured network of multi (two to eight) and single process pipe cryolines.



Basis of Risk, Analysis and its Mitigation

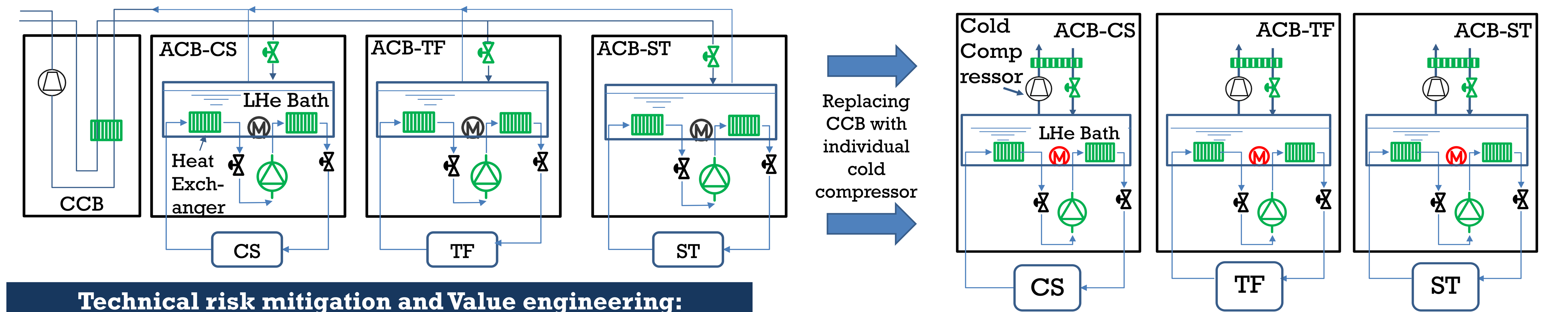
Likelihood of Occurrence	Impact or Consequence				
	Negligible (1)	Marginal (2)	Significant (3)	Critical (4)	Crisis (5)
Very Likely (5)	Low (5)	Medium (20)	High (45)	Very High (80)	Very High (125)
Likely (4)	Low (4)	Medium (16)	High (36)	High (64)	Very High (100)
Unlikely (3)	Low (3)	Medium (12)	Medium (27)	High (48)	High (75)
Very Unlikely (2)	Low (2)	Low (8)	Medium (18)	Medium (32)	High (50)
Not Credible (1)	Low (1)	Low (4)	Low (9)	Medium (16)	Medium (25)



ITER Cryodistribution System

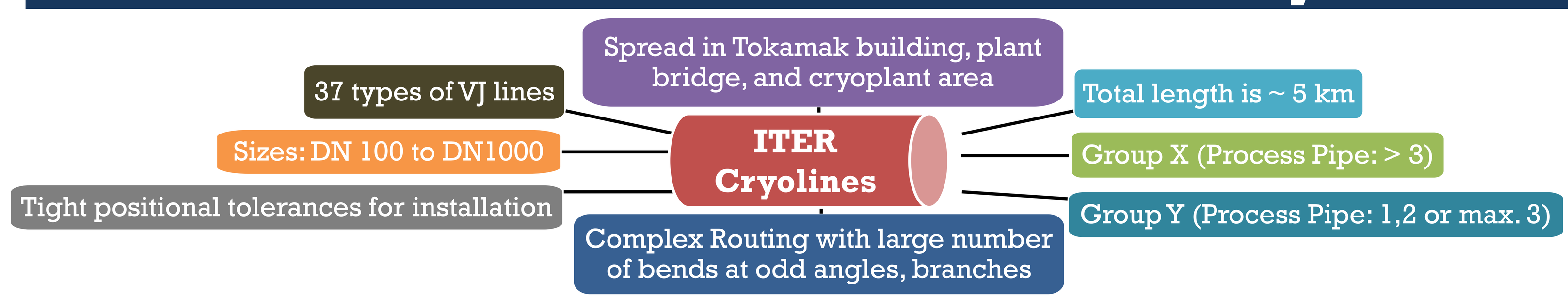
- The CD system of ITER is specifically configured for a fusion machine, meaning thereby managing of steady state heat load, dynamic heat load arising from the magnets system as well as nuclear heating and supporting the operational scenarios.
- In parallel to the conceptual design, market survey to identify the cryogenic industries that can strongly support to accomplish the CD project was started through the pre-qualification process

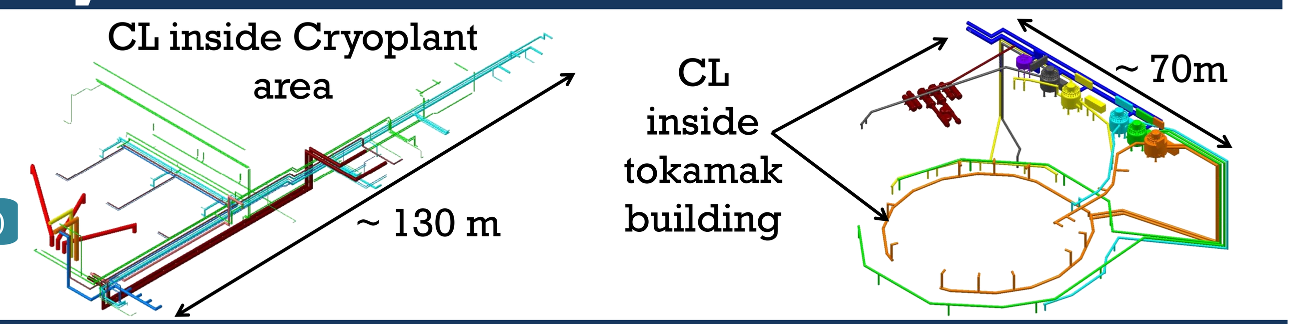
System optimization – Individual cold compressors over Common cold compressor



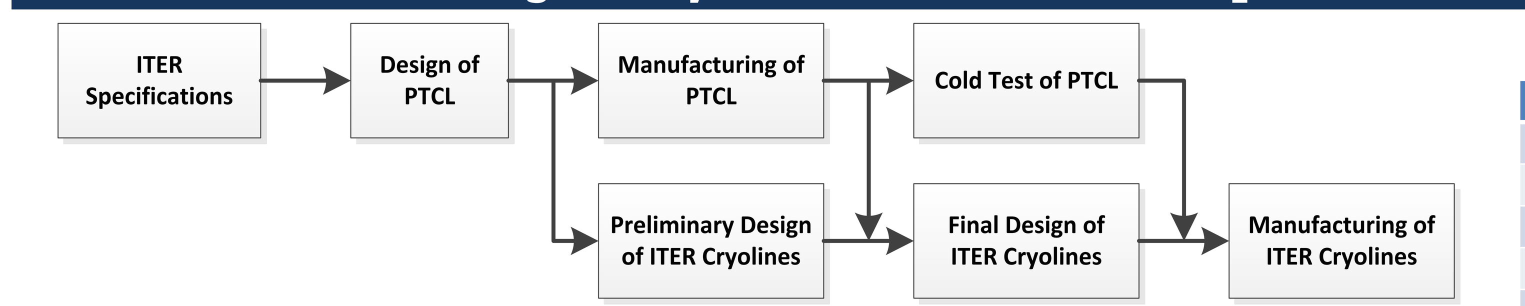
- Common cold compressor configuration, requires one cold compressor of capacity ~2.1 kg/s, which calls industrial up scaling or development.
- Individual cold compressors provide flexibility to operate each ACB at different temperature level as well as reduces the maximum mass flow rate for compressor.
- Maximum mass flow rate requirement is now restricted to 0.6 kg/s, 0.8 kg/s and 1.3 kg/s for ACB-TF, CS and ST respectively.

ITER Cryolines System





Planning and Synchronization – Development of Prototype Cryoline (PTCL) with ITER Cryolines



- The high risk zone due to the availability of 'limited resources of industrial partners' and their understanding on the technical specifications was found to have both direct and indirect cascading impact on the technical performance of the system of CLs for ITER.
- A four-step process was implemented starting from global expression of interest with pre-qualification, PTCL design followed by fabrication and test
- The technical uncertainty of the overall CL system was mitigated by selecting particular segments in the PTCL such as 'T', C-sections with different angles, straight section and a specific out of plane 'Z' sections.
- EN and PED harmonized standards for design, fabrication and materials for the ITER CLs were followed to satisfy the requirement of CE marking as the final use of the components will be in France

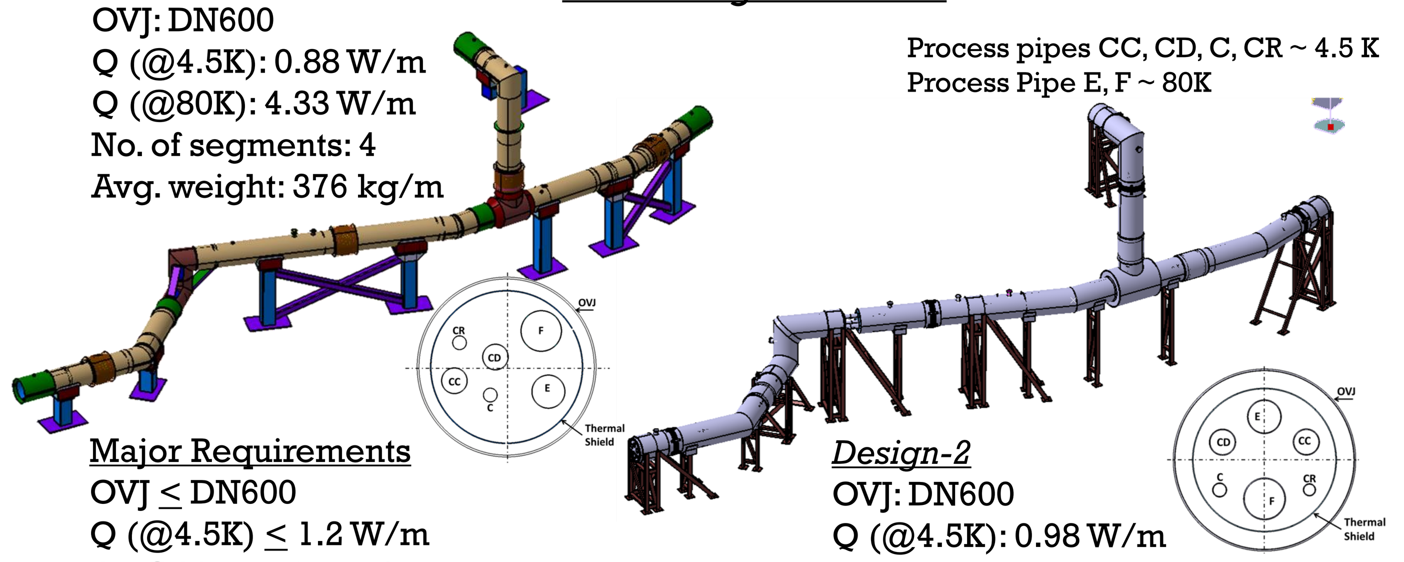
Major Technical specifications of ITER Cryolines and PTCL

Specifications	ITER Cryolines	PTCL
OVJ Size	DN 100 to DN 1000	DN 600
Number of process pipes	1 to 7	6
Length	~ 5000 m	27 m
Segments	Straight, Tee, Elbow, Z	Straight, Tee, Elbow, Z
Quality Classes	QC 1*, QC 2	QC 1
Seismic Classes	SC1 (SF)*, SC1 (S), SC2, NSC	SC1 (S)
Safety Classes	SIC-II*, SR, Non-SIC	Non-SIC
Fluids	Helium, Nitrogen	Helium
Temperature levels	4.5K, 50K, 80K, 300K	4.5K, 80K, 300K
Pressure of process fluid	Maximum 21 bar	21 bar (design), max. 6.5 bar (cold test)

*most stringent

Two designs of PTCL

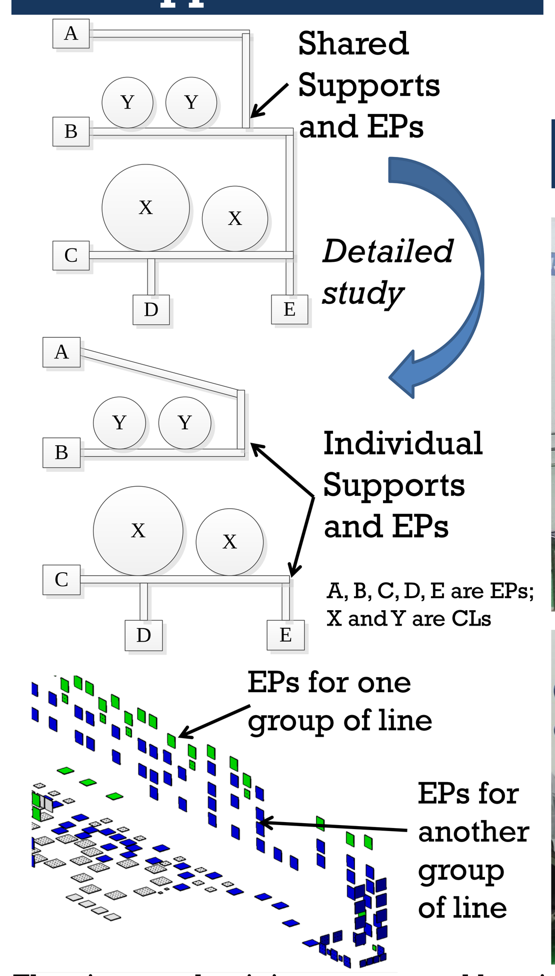
Design-1
OVJ: DN600
Q (@4.5K): 0.88 W/m
Q (@80K): 4.33 W/m
No. of segments: 4
Avg. weight: 376 kg/m



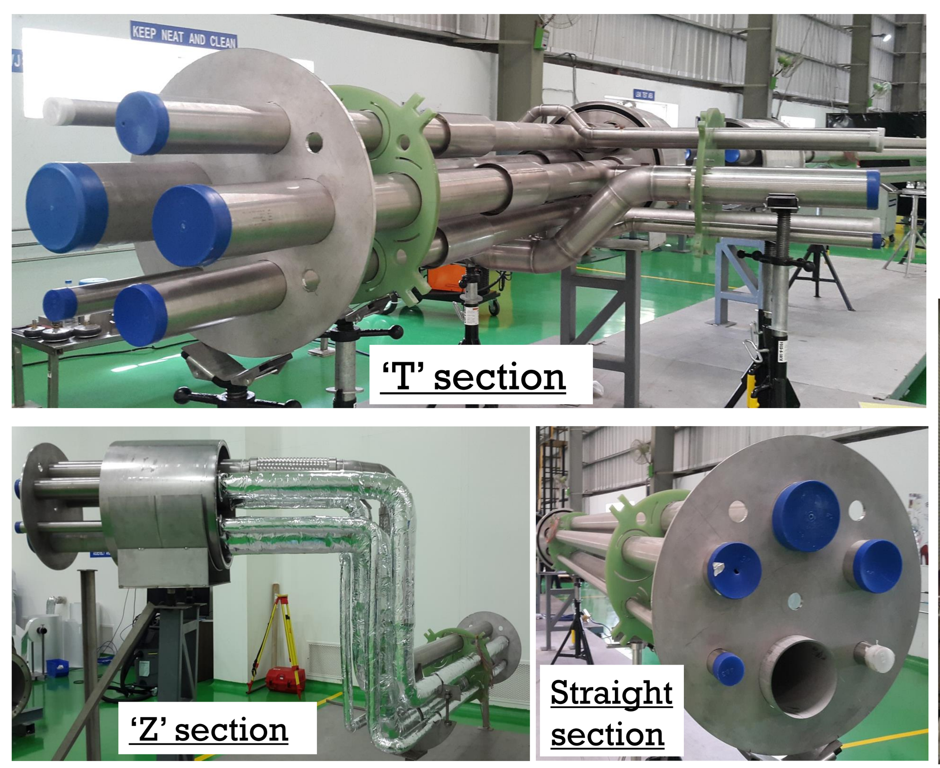
Major Requirements
OVJ ≤ DN600
Q (@4.5K) ≤ 1.2 W/m
Q (@80K) ≤ 4.5 W/m
No. of segments: shall be minimized
Avg. weight: shall be minimized

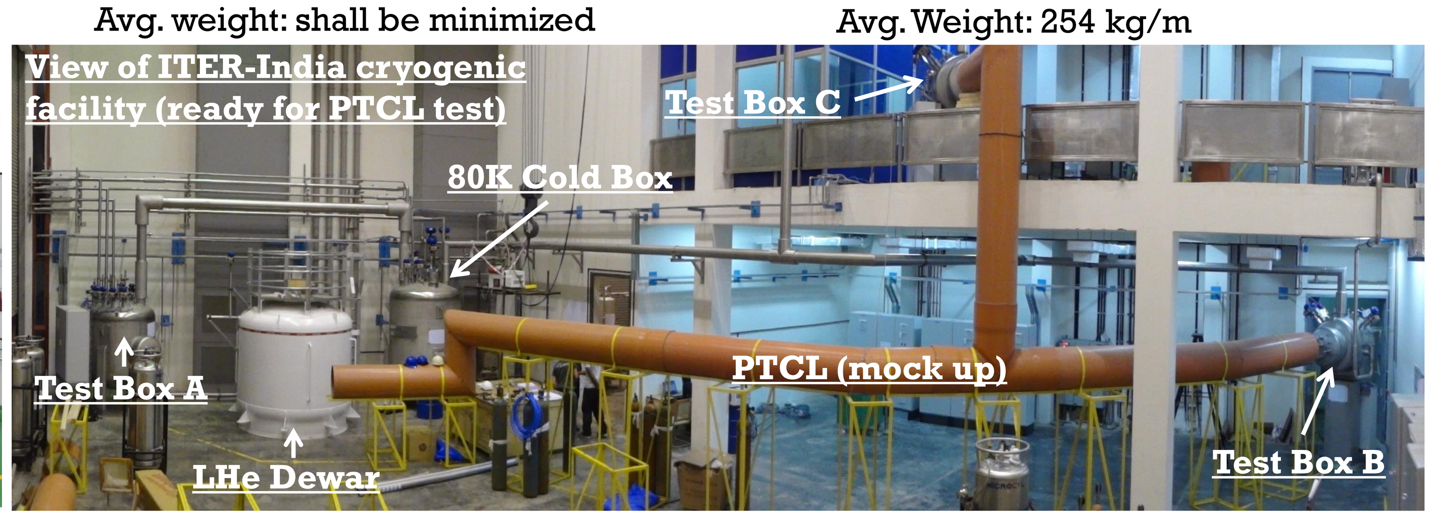
Design-2
OVJ: DN600
Q (@4.5K): 0.98 W/m
Q (@80K): 3.73 W/m
No. of segments: 5
Avg. Weight: 254 kg/m

Separation of External supports & EPs



PTCL in Manufacturing phase

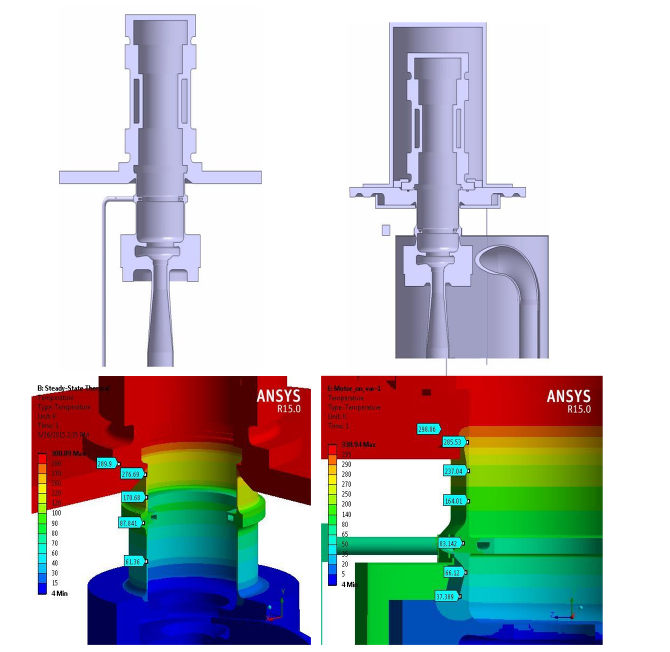




Technical risk mitigation and Value engineering: Cold Circulating Pumps and its test

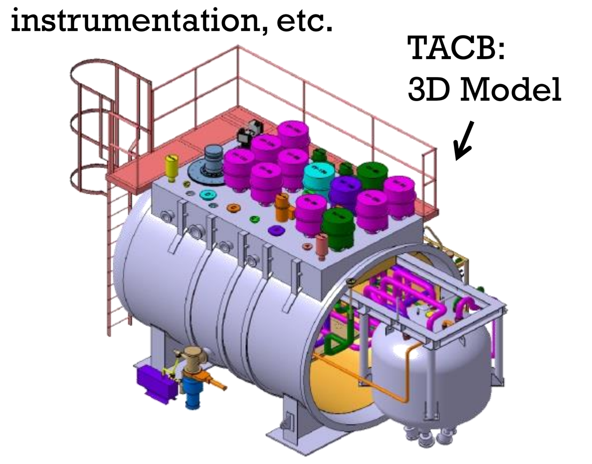
Cold Circulating Pumps (CCP)

- First of a kind technical specification in terms of mass flow, pressure head and variation in input conditions (i.e. P & T). In all modes of operation inclusive of 110 % of mass flow, more than 70 % efficiency required.
- By optimization of the position of thermal intercept with respect to the flange, it has been possible to increase the temperature from 289 K to 298 K satisfying the requirement.



Test ACB (TACB)

- Developed taking in to account the technical requirements of the major components such as CCPs, valves, heat exchangers, filters, instrumentation, etc.



Conclusion

- 'Very high' and 'high' risks brought down to 'medium' and 'low' level with implementation of prototyping both in CD and CL
- The PTCL design, the development of two CCPs by two industrial collaborations - a blessing towards the further development
- Above planning and actual implementation as well as value engineering has enabled ITER-India to enter in to the industrial level of development for CL and CD system of ITER.

Acknowledgements

Authors would like to thank the colleagues from ITER-India, ITER Organization in St. Paul Lez Durance France as well as industrial partners namely M/s INOX India Limited (India) and their consortium partner, M/s Air Liquide Advanced Technologies (France), M/s Linde Kryotechnik (Switzerland), M/s Barber Nichols Inc. (USA), M/s IHI (Japan), M/s Tayyo Nippon Sanso (Japan)

References

1. Serio L et al., The Cryogenic System For ITER, *Fusion Science and Technology*, Volume **56**, p. 672-75
2. Chang H.-S., Serio L., Henry D., Chalifour M. and Forgeas A., Operation Mode Studies Of The ITER Cryodistribution System, *Advances in Cryogenic Engineering*, 2012, p. 1691-98
3. Klein J. H. and Cork R. B., An Approach to Technical Risk Assessment, *International Journal of Project Management*, Volume **16**, No. 6, p. 345-51
4. Shah N, Bhattacharya R, Sarkar B, Badgujar S, Vaghela H and Patel P, Preliminary system design and analysis of an optimized infrastructure for ITER prototype cryoline test, *Advances in Cryogenic Engineering*, Volume **57**, p. 1935-42
5. Shah N, Sarkar B, Choukekar K, Bhattacharya R and Kumar Uday, Investigation of Various Methods for Heat Load Measurement of ITER Prototype Cryoline, *Advances in Cryogenic Engineering*, Volume **58**, p. 856-63
6. Vaghela H., Sarkar B., Bhattacharya R., Kapoor H., Chalifour M., Chang H.-S. and Serio L., Performance evaluation approach for the supercritical helium cold circulators of ITER, *Advances in Cryogenic Engineering*, 2014, p. 872-79
7. P. C. Rista, J. Shull, B. Sarkar, R. Bhattacharya and H. Vaghela, Engineering, Manufacture and Preliminary Testing of the ITER Toroidal Field (TF) Magnet Helium Cold Circulator, *CEC/ICMC 2015*, (C1OrC-05)

Presented at the Cryogenic Engineering Conference and International Cryogenic Materials Conference, 2015 June 28-July 2, Tucson, Arizona; Program I.D. number: C1PoD-08 [C30]