Force cooled Quench Tanks for the ITER cryogenic system

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Introduction

*The ITER cryogenic system has an overall helium inventory **~24 tons** with over **7 tons** contained in TF magnets. Design input data and assumptions for the Quench Tanks are outlined. The studies performed in order to choose the most appropriate design solution for the Quench Tanks are presented. The chosen design and associated validation studies to demonstrate feasibility and ensure the required performance are also described.*

Quench Tanks – double walled perlite insulated horizontal vessels actively cooled to ~80K. Volume of 2*360=**720 m^3**. Length – 35m, Dia. – 4.5m (Fig.1). Required for:

- Capturing He gas after magnets' quench;
- Storing He inventory during non-operational phases.

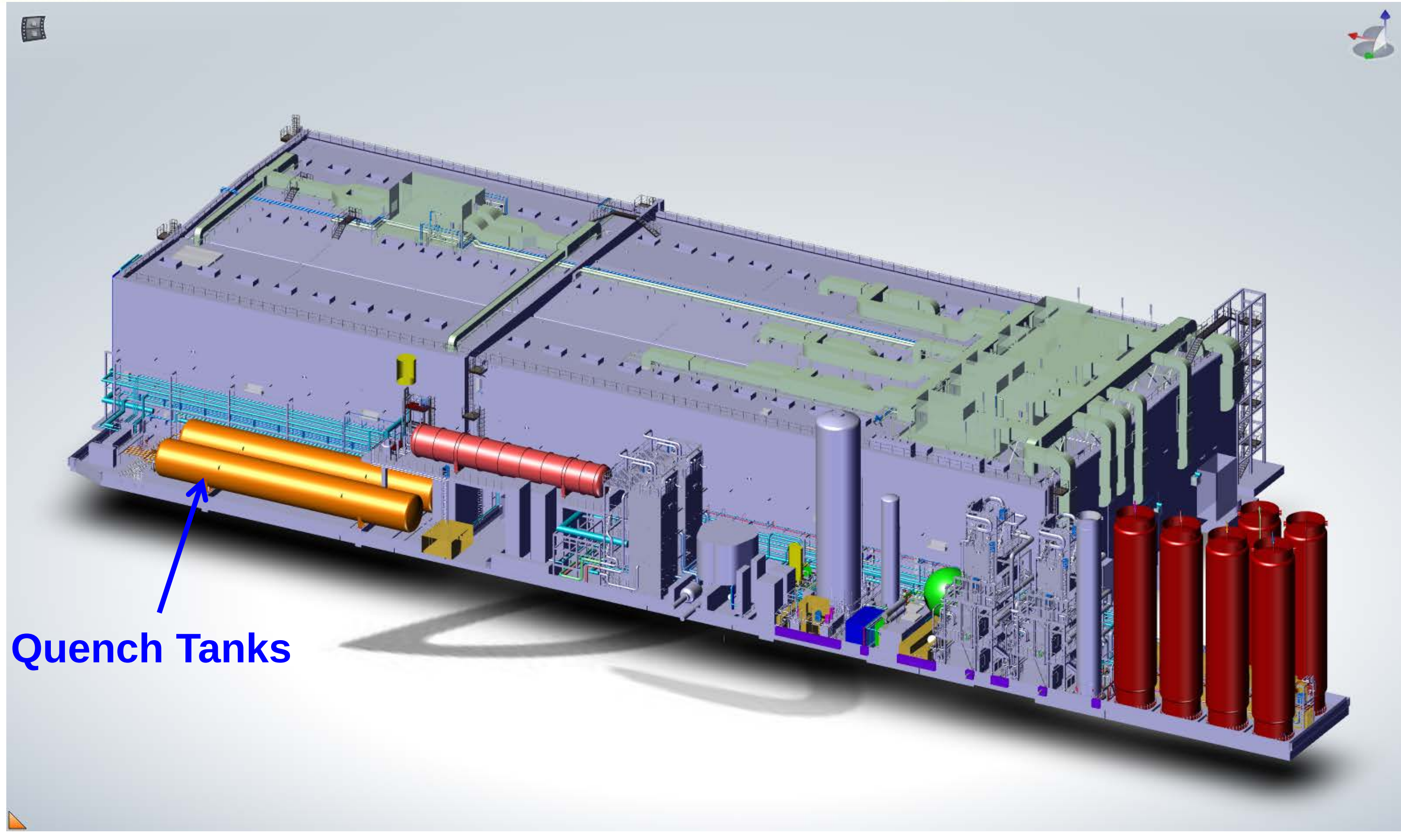

FIG.1: General view of the cryoplant and Quench Tanks

Design input data

Design parameter	Value	Units
Stored gas mass	~7	tones
Total cold volume	2*360	m^3
Storage temperature	<86	K
Stand-by temperature	~100	K
Storage pressure	1.8	MPa-a
Stand-by pressure	0.12	MPa-a
Max. inlet gas flow	~100	kg/s
Max. allowable heat load	2*1500	W

Table 1: Design input data

Selection of design solution

'Warm' design

❖ **Quench Tanks with gas diffusers** – high probability of local wall cooling below brittle transition -> risk of vessel rupture;
❖ **Quench Tanks made from stainless steel** – high cost;
❖ **Quench Tanks with external regenerators** – too big, complex and expensive for given mass flow;
❖ **Quench Tanks with built-in regenerators** – risk of cold gas 'breakthrough' and lack of industrial references.

Active cooling

❖ **Quench Tanks with inner pressure vessel cooled by independent cooling loop (Fig.2 and Fig.3):**

- Complexity of manufacturing and inspection;
- Possible poor performance of the cooling loop;
- Risk of damaging the cooling loop during cool-down or operation.

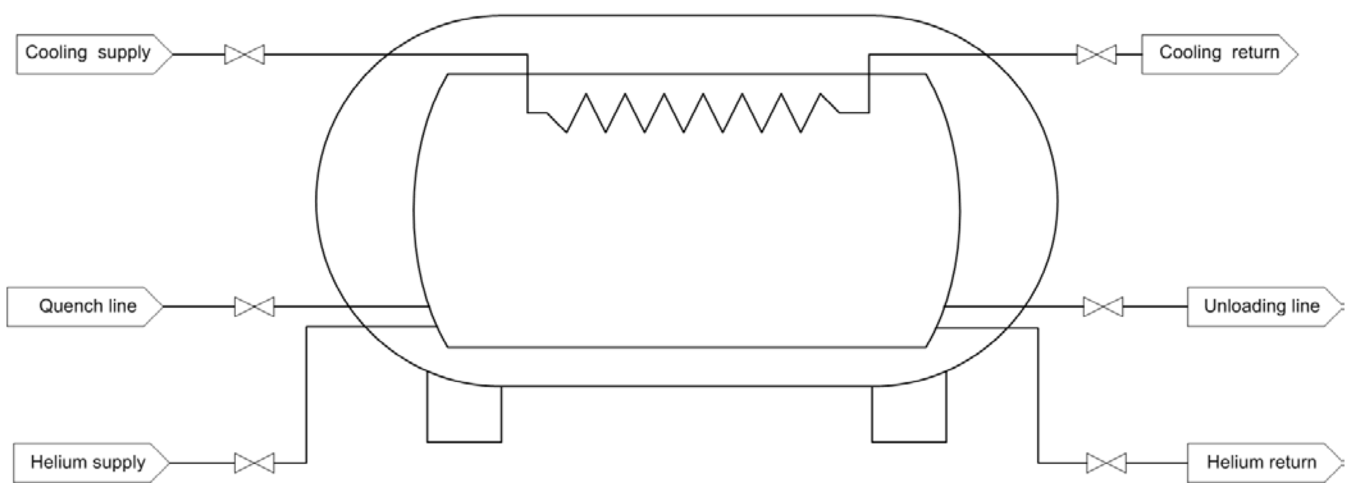

FIG.2: Quench Tank with built-in cooling loop heat exchanger (simplified PFD).

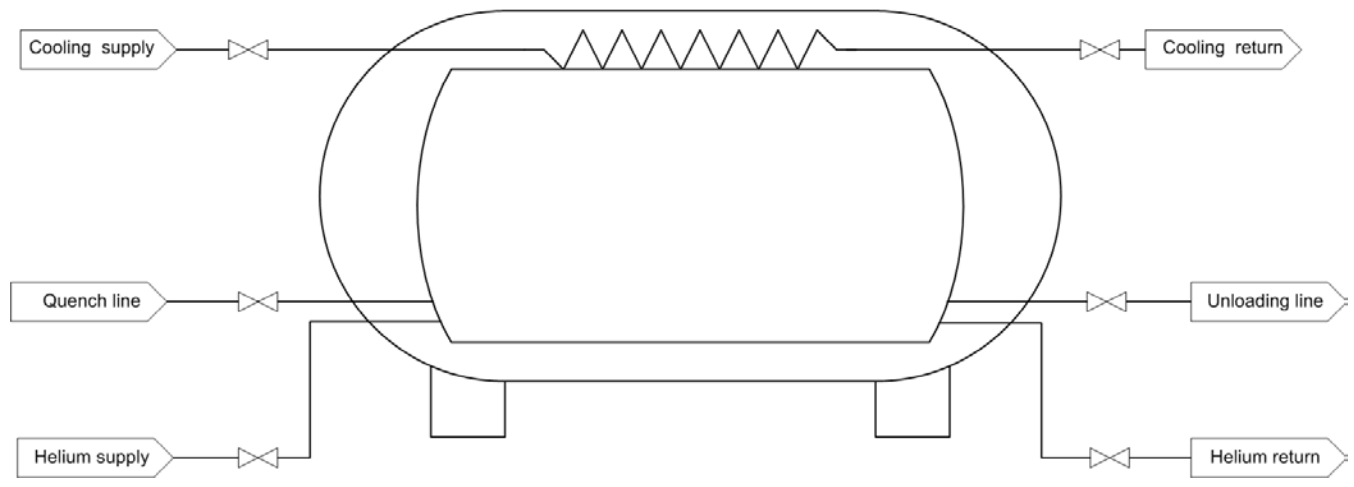

FIG.3: Quench Tank with attached cooling loop heat exchanger (simplified PFD).

Quench Tanks with independent LN2 cooled thermal shield (Fig.4):

- High inner vessel weight supporting within the shield, so multiple supports shall be used;
- Weak thermal link between the shield and inner vessel;
- Lack of references and manufacturing complexity of the solution;
- Necessity of extensive follow-up of design and manufacturing.

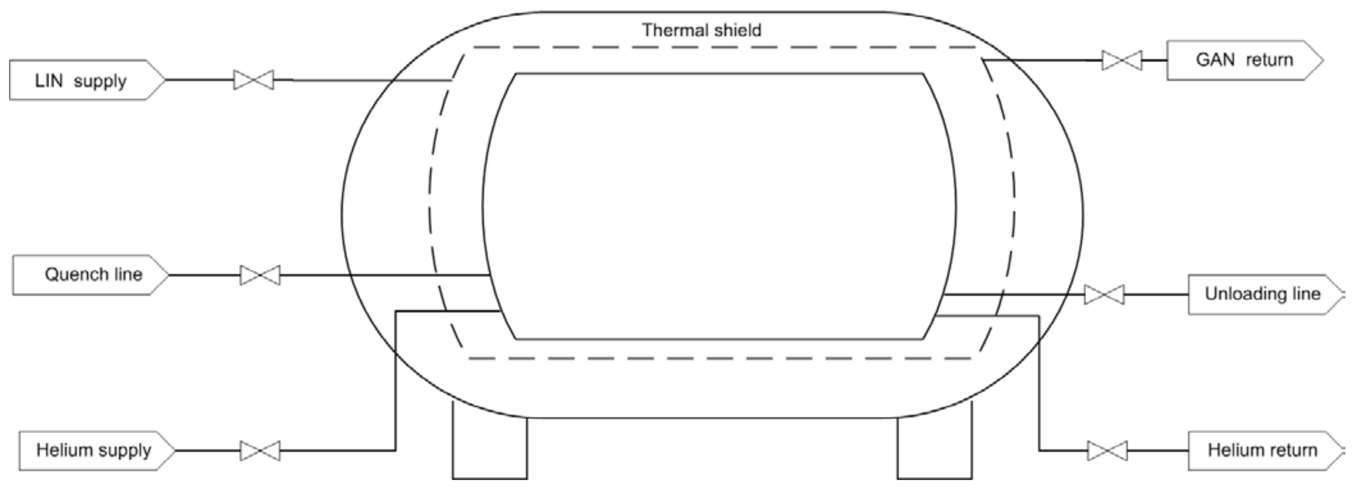

FIG.4: Quench Tank with independent LN2 cooled thermal shield (simplified PFD).

Quench Tanks with gaseous He circulation through the inner pressure vessel (Fig.5):

- Simplified design;
- Risk of gas thermal stratification inside the inner vessel.

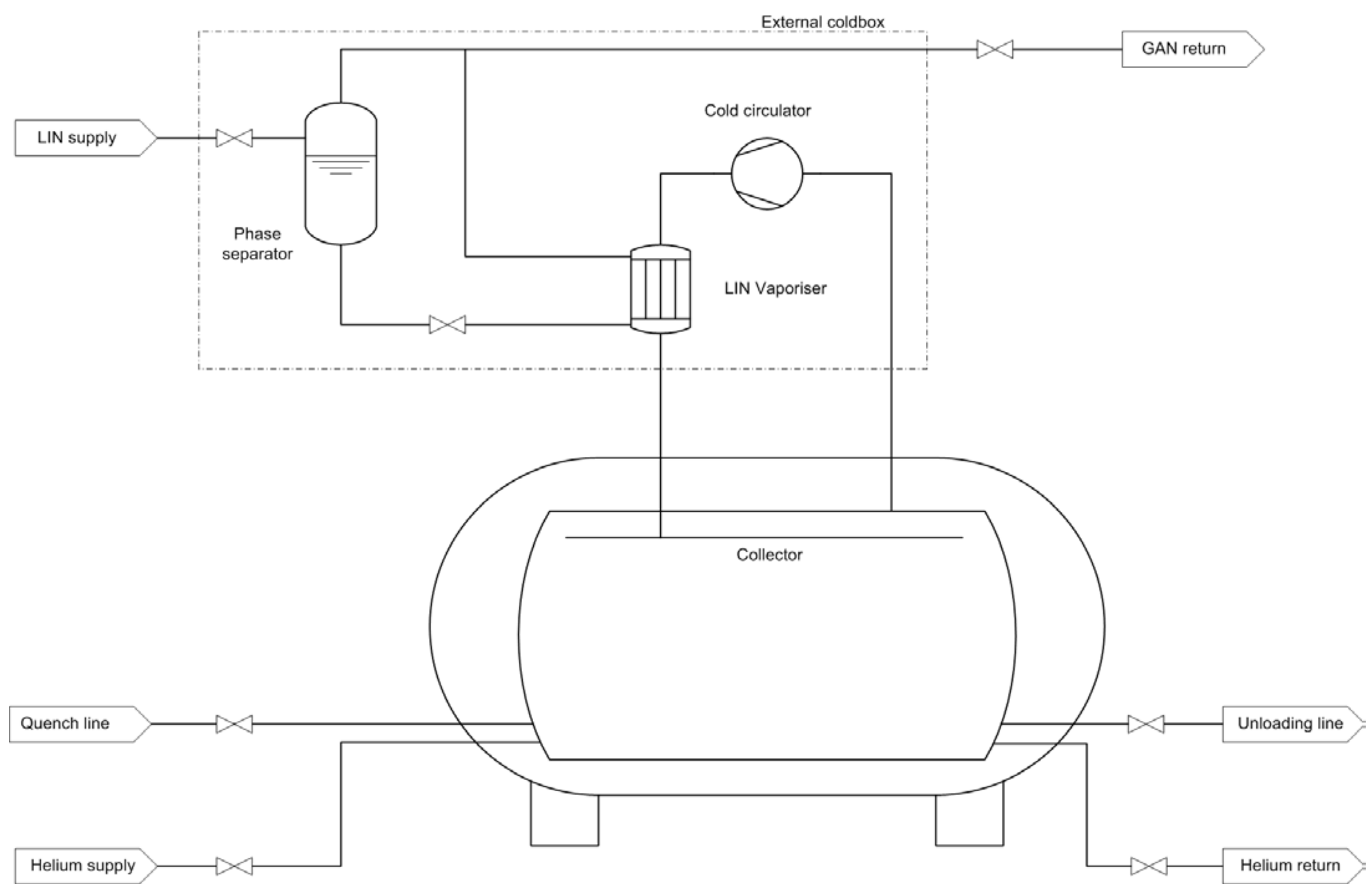

FIG.5: Quench Tank with with GHe circulation through the inner pressure vessel (simplified PFD).

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Design of Quench Tanks and cooling loop

Quench Tanks:

- Guarantying a robust design (including quench with high gas flows entering the inner vessel and seismic events) – see Fig. 6;
- Minimizing heat loads onto the inner vessel, caused by supports, piping and gas in the incoming line – see Fig.7.

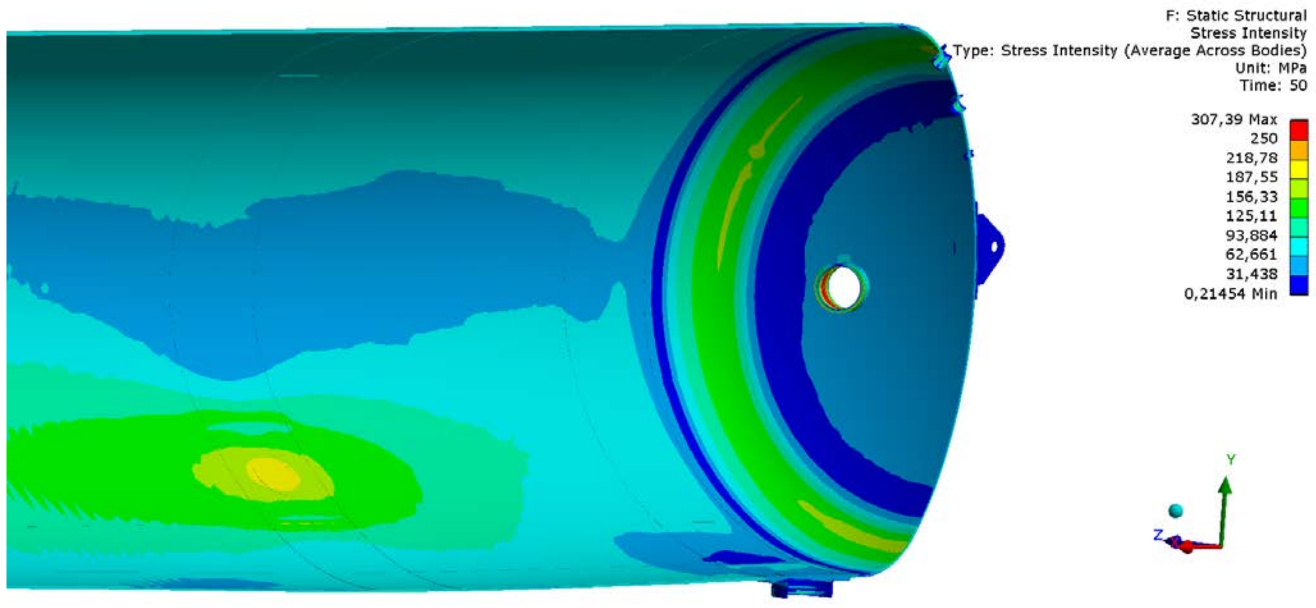

FIG.6: Example of calculated stress intensity distribution.

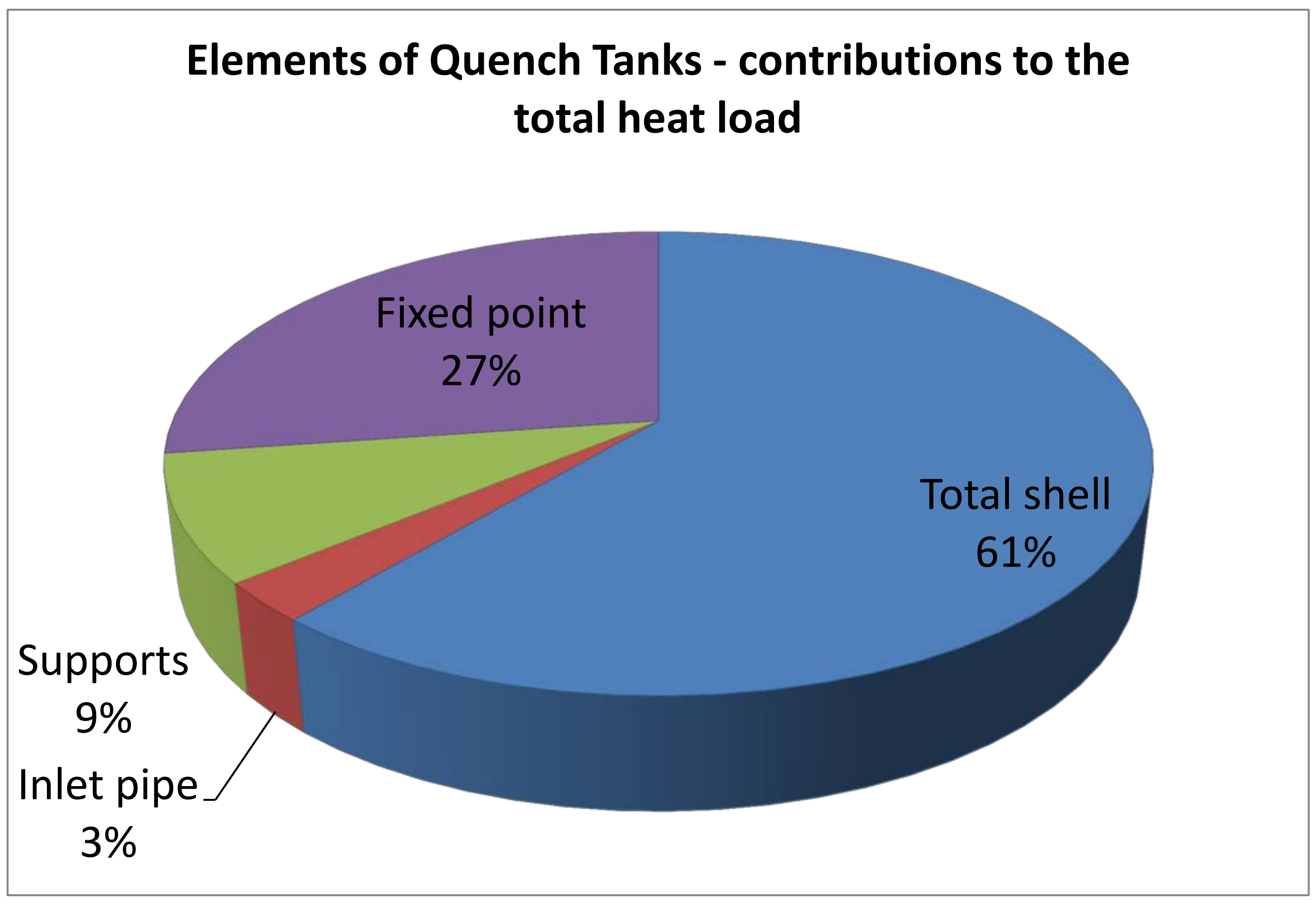

FIG.7: Contributions of Quench Tank elements to the total heat load.

Quench Tanks cooling loop:

- Ensuring efficient operation for storage and stand-by modes – see Fig.8;
- Protection of the cooling loop during a quench – see Fig.9;
- Minimizing gas stratification inside Quench Tanks – see Fig.10.

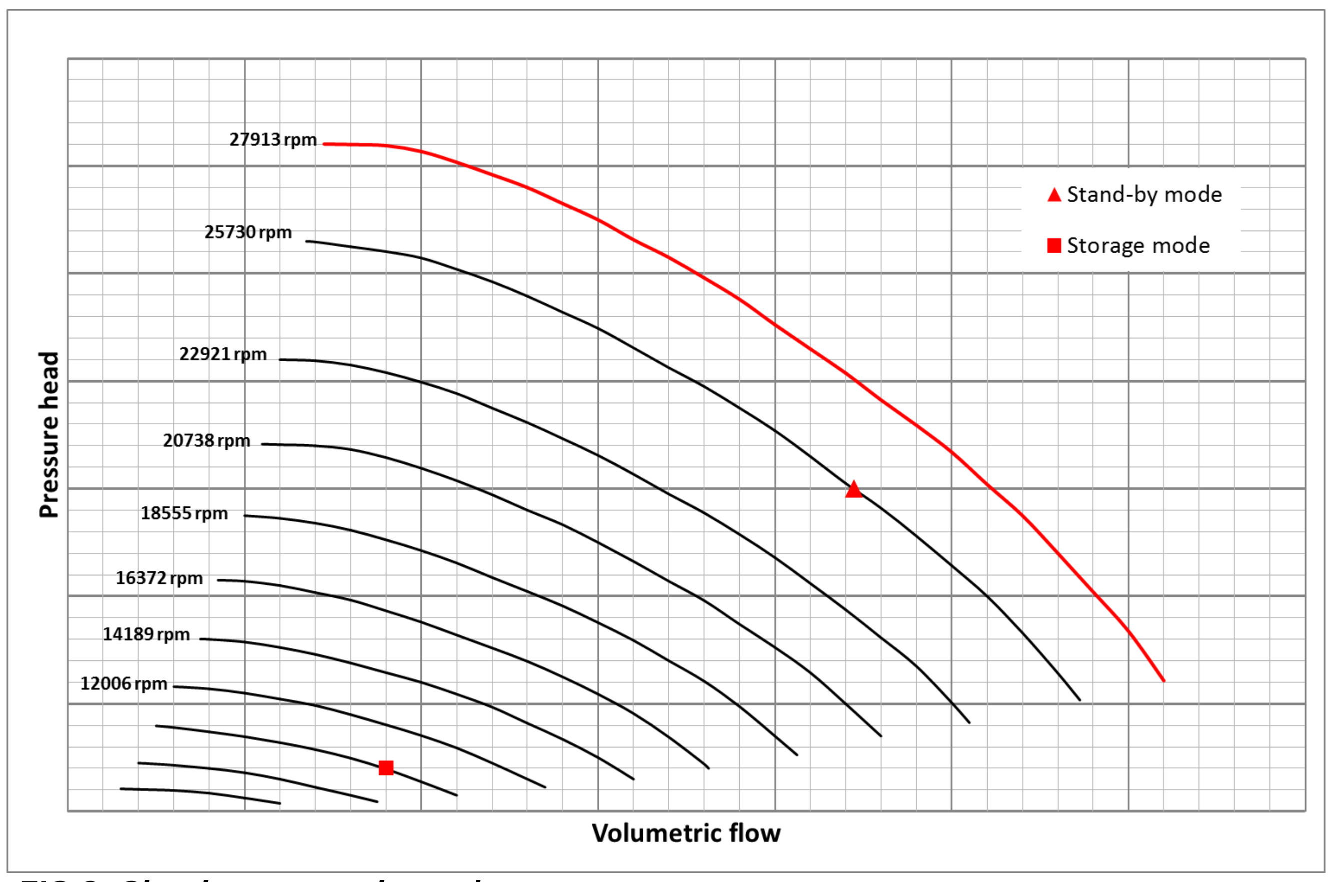

FIG.8: Circulator operating points.

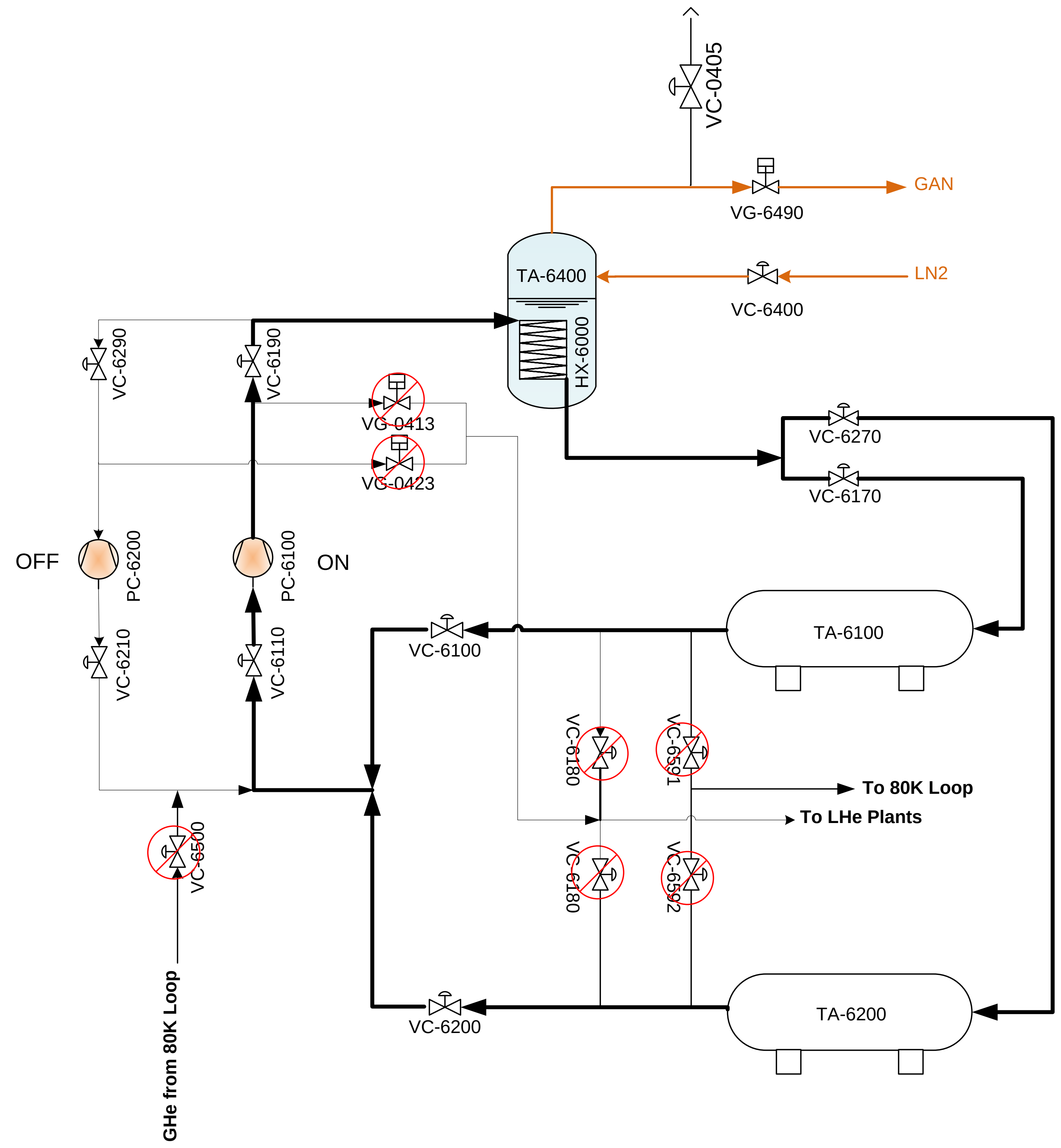

FIG.9: Simplified PFD of QTs and circulators' cold box.

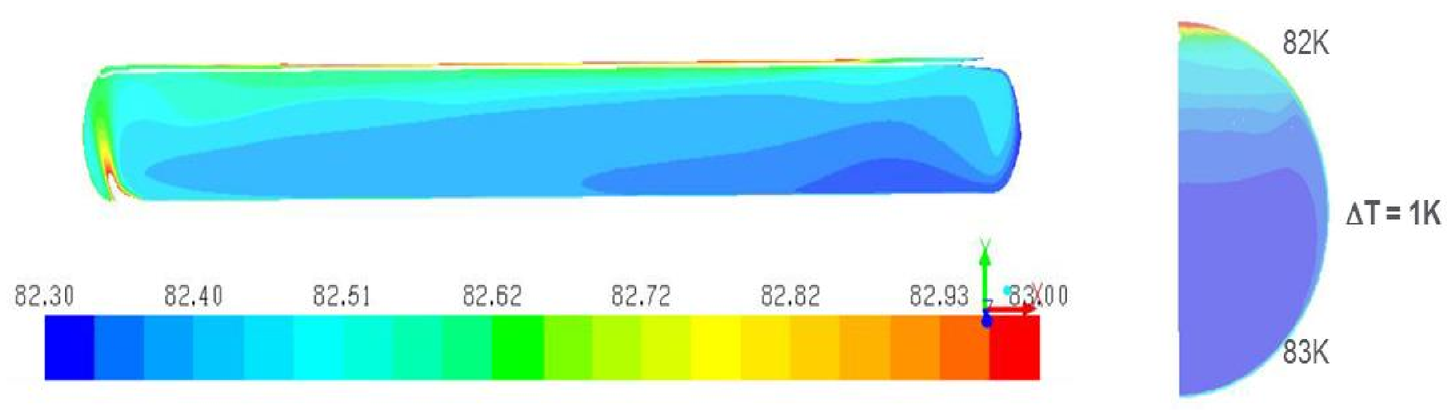

FIG.10: Temperature map (K) of the inner vessel in storage mode.

Current state:

- The Quench Tanks manufactured and factory tested;
- The Quench Tanks delivered to the ITER site at the end of 2016 (see Fig.11);
- The cold box for the external circulation loop manufactured and factory tested;
- The cold box will be delivered on site by the end of summer 2017;
- Installation of the equipment is planned for 2018.

FIG.11: Quench Tanks after delivery to ITER site in Cadarache.