The Heat Rejection System of the ITER Reactor

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Abstract

ITER will be the largest fusion experimental reactor in the world designed to reach the first plasma at mid of 2018. ITER is being designed to demonstrate the technological feasibility of the nuclear fusion energy conversion, at plant scale, from high temperature Deuterium-Tritium plasma using the TOKAMAK magnetic confinement arrangement and with a power amplification at least of 10. The ITER design experience, the effort in developing the leading-edge technologies and the knowhow acquired during its operation will guide the realization a proper long-term R&D fusion programme. ITER will bridge the gap between Nuclear Fusion and the large scale commercial production of electricity at competitive cost with other sources by 2045.

ITER will have a large Vacuum Vessel that hosts the Plasma facing components. These components include the Blanket and the Divertor that will operate at temperatures, heat loads and neutron flux higher than that of reached in a nuclear fission power plant reactor.

Among others, one of the main critical issues of the ITER reactor is the transfer of the heat generated in the Plasma, during the D-T reaction, through the Tokamak Cooling Water System (TCWS), to the intermediated closed loop Component Cooling Water System (CCWS) and then, via the open loop Heat Rejection System (HRS) to the environment. The HRS also absorbs heat through the CCWS from other non nuclear systems like the Chilled Water System (CHWS), the Cryogenic System, the Steady State Electrical Power Network (SSEPN) and other auxiliary systems. The HRS rejects to the environment all the heats from the ITER components (nuclear and non nuclear) with the only exception the Vacuum Vessel whose heat are released via a separate primary heat transfer system to the air coolers. The HRS is based on a Cooling Towers System (CTS) designed to release to the environment up to

450 MW whilst the total peak value produced during the DT pulse is about 1270 MW (35% of duty cycle).The CTS requires both high make up water and blowdown flow rates, which in turn demand stringent water chemistry control to limit the possible loop contamination.

This paper describes the main design modifications and optimizations recently introduced with a closed intermediate CCWS and an open HRS system.

The main benefit are the minimization of the capital and operating costs, the optimization of the piping layout, the introduction of a second containment barrier to the gaseous and liquid radwaste releases and the relevant minimization of the impact to the environment.

The Heat Rejection System (HRS)

The HRS provides the final heat sink and rejects all heat loads in the ITER plant with the exception of the Vacuum Vessel.

The main HRS clients are, Fig 1: i) CCWS/1 or the secondary circuits of the main Primary heat Transfer Systems (PHTS) of the TCWS, ii) CCWS/2 or the secondary circuits of the CHWS, the Cryogenic System, the Steady State Electrical Power Network (SSEPN) and other auxiliary systems.

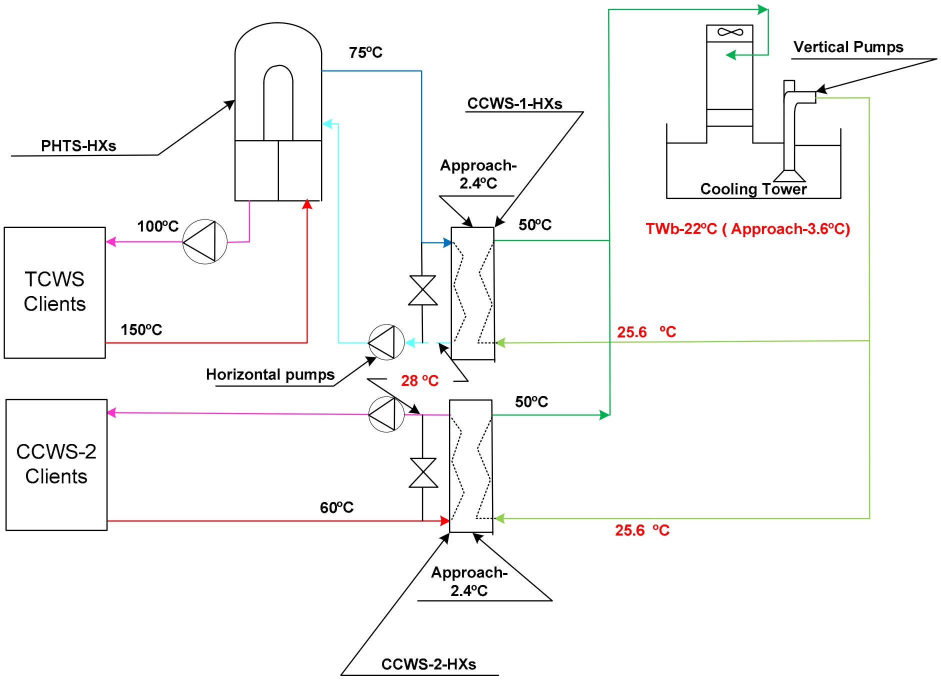


Fig. 1 – ITER Cooling Water System

The introduction of this further CCWS/1 closed loop permits the control of the possible releases of gaseous and solid nuclear products from the TCWS to the HRS. Therefore, the secondary water loop is daily controlled to prevent any normal and abnormal release of contaminants to the HRS.

The HRS consists of the Cooling Tower System (CTS), with 4 air forced/induced draft main units, the water basins, the Vertical Pumps together with the associated water make up and blowdown systems. Whilst the CTS transfers the heat from the CCWS to the atmosphere, the water basin and its ancillary circuits have the following objectives:

1) Provides buffer heat capacity by proper basic water storage to average the heat load during pulsed operation.
2) Provides makeup and blowdown flows to perform the chemical control of the salt concentration in the water basin and to prevent the growth of biologic species (i.e. algae).

The HRS, Fig. 1, provides supply water for the CCWS clients at a maximum temperature of 28 °C and accepts return flow at a maximum temperature of 50°C.

The heat load during the pulse operation are 1270 MW of which 1030 MW in the CCWS/1 from the main PHTS of the TCWS (715 MW from FW/BLK PHTS, 200 MW from DIV/LIM PHTS, and 100 MW from NB injector PHTS), 190 MW from the other CCWS/2 and other 50 MW from the CHWS. The heat load during the dwell condition is 150 MW. The main contributors to the heat load during the dwell condition are the CHWS and the CCWS.

Cooling Tower System (CTS)

The CTS thermal design parameters and features are respectively reported in the Table I and II, whilst the configuration of the wet type CTS along with its bottom basin is shown in Fig. 2. Based on ITER site conditions at Cadarache (France), the wet type CTS consists of 4 cooling cells arranged in an array of tower structures. The overall size of the complete cooling tower envelope is about 62 m (L) x 38 m (W) x 20 m (H), considering two rows of 8 cells (two cells in one unit). The design of the CTS, including the basin, is based on a cost minimisation between cooling tower heat rejection capacity and temperature levelling capability in the basin.

The basin volume is designated as 20.000 m^3, almost equivalent to the circulation volume in one pulse repetition duration (1,800 s) of the reference plasma. This volume allows about 10 hr of pulsed campaign without the water supply. The CTS wet bulb design temperature has been assumed at 22 °C at ITER site at Cadarache. Therefore, in summer (for 45 day from mid July to end August) there is the possibility of CTS operation during the day above the design limit when the wet bulb could statistically reach a peak of 33 °C. In that case, the basin volume provide proper thermal capacity to permit daylight operation (10 h) at the reference design with two silent shifts operation during the night (14 h) to reduce the temperature in the basin. The impact of this possible temporary limitation has been considered negligible on the general machine availability. Both the four units of the cooling tower and the water basin design data have also been positively checked to maintain the cooling requirement during the ITER Non-Inductive Operation I with the pulse duration of 3,000 s at 350 MW of fusion power. The four CTS vertical pumps have 4200 m3/h and 60 mH2O of head capacity, Fig. 3.

Operation Condition	**Reference Plasma**		**Non-Inductive**
Parameter	**Pulse**	**Dwell**	**Burn**
Peak heat duty (MW)	1.270	150	900
Duration (s)	400	1.400	3.000
Flow rate (kg/s)	11.620		
Peak inlet temperature (C)	50	38	55
Max. outlet temperature (C)	25.6	25.6	25.6
Wet bulb temperature (C)	22	22	22
Water basin volume (m^3)	20,000		

Table I - CTS Thermal Design Parameters

Parameter	**Specification**
Number of towers	4
Cells per tower	2
Fans per unit	1
Fan motor (kW)	300
Vertical pump flow rate (m3/h)	4200
Vertical pump head (mH2O)	60

Table II - CTS Design Features

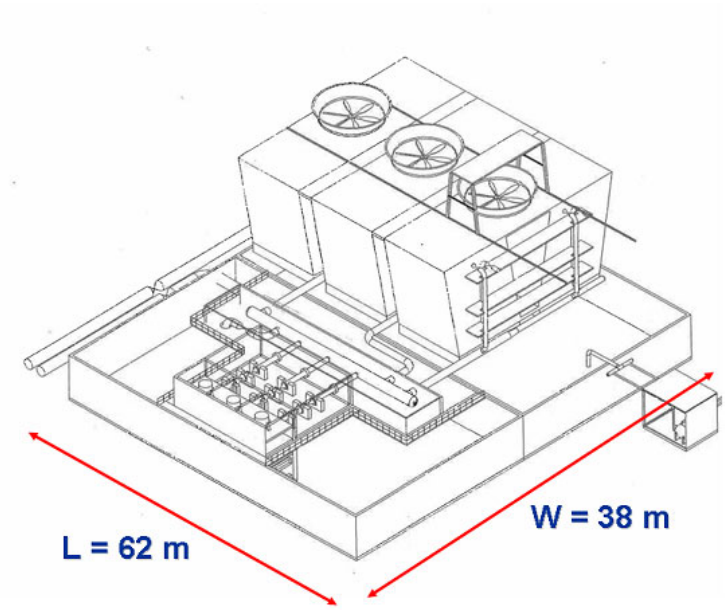
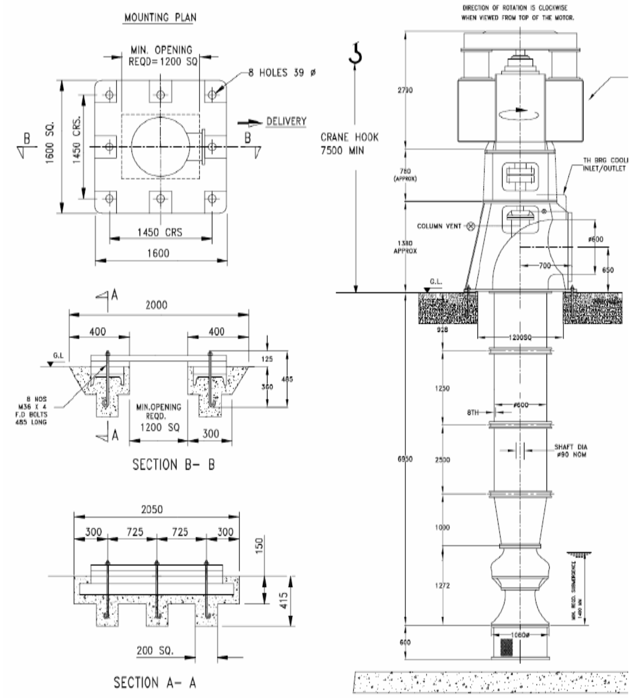


Fig. 2 - Cooling Tower Systems



Approximate Weight of the pumpset – 15,000 kg
Above dimensions are tentative and for reference only.

Fig. 3 – CTS Vertical pump

Layout of the HRS

The layout of the HRS is shown in Fig. 4. The pump station and the heat exchangers of the CCWS 1/2 are located on the south side of the CTS and water basin.

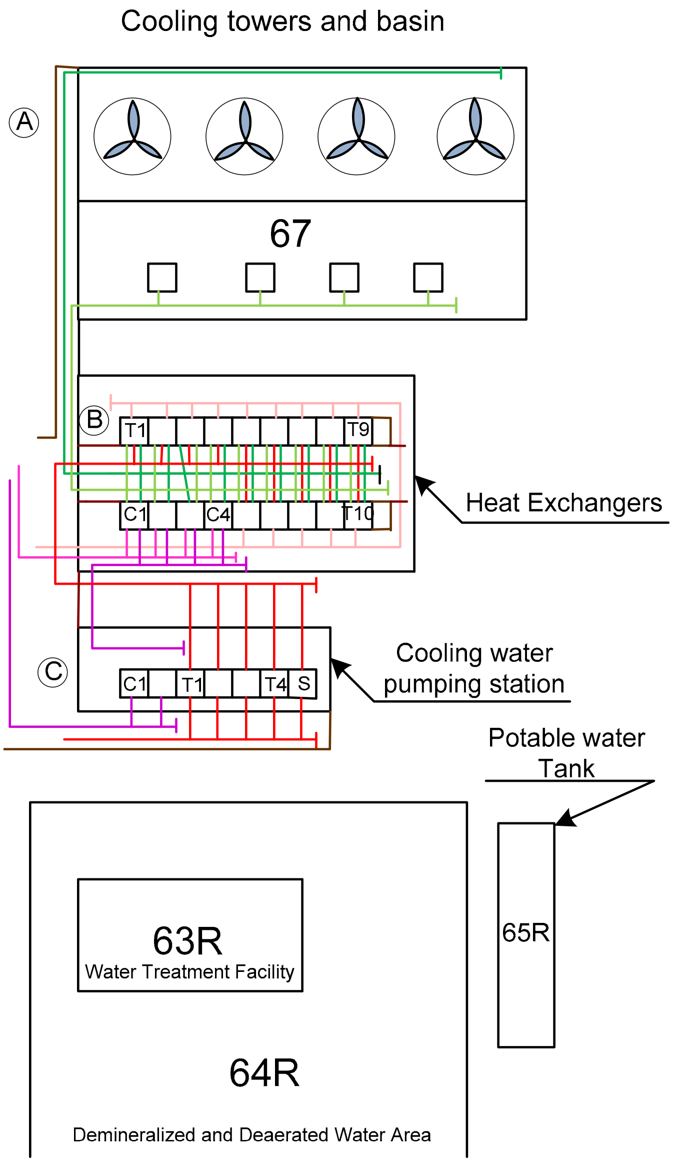


Fig. 4 – Layout of the HRS

Conclusions

The ITER Cooling Water System has been recently modified by introducing two closed intermediate Component Cooling Water Systems (CCWSs) to transfer the heat generated in the Plasma and in its auxiliary equipments to an open Heat Rejection System (HRS).

These design modifications will give as main benefit the minimization of the capital and operative costs, the optimization of the piping layout and the reduction of its length, the standardization of the CCWS pump and heat exchanger units.

Another beneficial effect is because the closed CCWS represents a second containment barrier against the possible release of contaminants, both in gaseous and liquid form, from the primary heat transfer nuclear systems to the environment.