The environmental impact of the Cooling Water System of the ITER Reactor

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Abstract

ITER is the largest fusion experimental reactor in the world designed to reach the first plasma at mid of 2018. ITER is 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 Nuclear Fusion toward the large scale commercial production of electricity at competitive cost with other sources by 2045.

ITER is provided with a Cooling Water System (CWS) designed to rejects to the environment all the heats generated from the components (nuclear and non nuclear) using water as coolant in Primary Heat Transfer Systems (PHTSs). The only exception is the Vacuum Vessel (VV) whose heat is released, via a separate heat transfer system, to the air coolers. The total heat to be released to the environment during the DT pulse is about 1270 MW by water via the Heat Rejection System (HRS) and Cooling Tower System (CTS) plus about 13 MW mainly from the VV (10 MW) and other systems (3 MW) by air coolers.

Among others, one of the main critical issues of the ITER reactor is the minimization of the releases of all the gaseous, liquid and solid effluents from the PHTSs to the environment.

This paper describes these main releases from the CWS (PHTSs, HRS and CTS), both during normal operations and main periodical maintenance.

ITER Cooling Water System

All the heat generated in the Plasma, during the D-T reaction, will be transferred, through the Tokamak Cooling Water System (TCWS and PHTSs), 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 heats 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.

In Fig.1 is shown the main organization of the ITER Cooling Water Systems

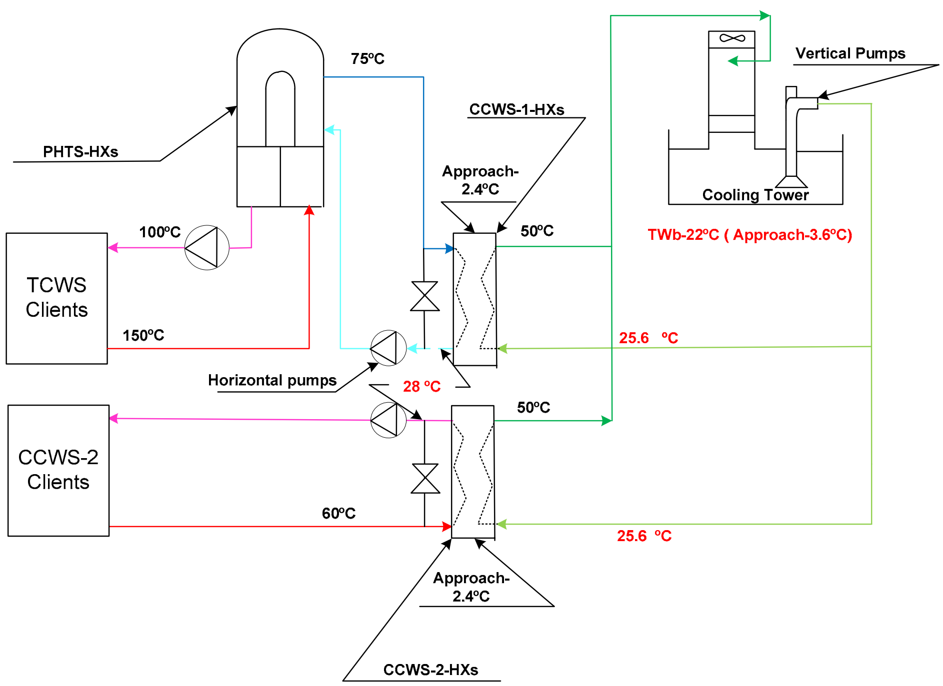

Fig. 1 – ITER Cooling Water System

The Tokamak Cooling Water System (TCWS)

The TCWS consists of PHTSs, the chemical and volume control systems (CVCSs), the draining and refilling systems, and the drying system.

During plasma operation, the PHTSs transfer heat generated in the components to environment via the intermediate closed component loops Cooling Water Systems (CCWSs) to the Heat Rejection System (HRS) by the Cooling Tower Systems (CTS).

In between pulses the PHTSs remove decay heat from the plasma facing components (First Wall Blanket and Divertor) as well as from the Vacuum Vessel.

There are 7 PHTS loops as follows:

- 3 loops for the First Wall and Blanket (FW/BLK) PHTS,
- 1 loop for the Divertor and Limiter (DIV/LIM) PHTS,
- 2 loops for the Vacuum Vessel (VV) PHTS, and
- 1 loop for the Neutral Beam Injector (NBI) PHTS.

The VV PHTS has a safety role in that it provides the ultimate decay heat removal even when the other PHTSs are not available during some very severe accidental events.
The safety role of the other PHTS loops for in-vessel components is limited to the confinement of radioactive inventory. The containment walls of the in-vessel PHTS loops are safety important class (SIC) because of their confinement function, however the active function of the PHTSs is non-SIC except some insulation valves.

The introduction of this further CCWS/1 closed loop permit 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 main PHTSs are provided with the Chemical and Volume Control System (CVCS), one for each in-vessel component PHTS (FW/BLK, DIV/LIM, and NBI), whose function is to control the water chemistry of the PHTSs, to manage the level control in the PHTS loops, to provide the main pump cooling, and to provide spray flows for pressurizer pressure control.
Each CVCS unit contains inlet/outlet mechanical filters to trap the Activated Corrosion Products (ACP) produced in the water loops by disposable stainless steel cartridges.

The CVCSs are also provided with Ion Exchange Resins bed demineralisers. Both the mechanical filters and the resin bed demineralisers are surrounded by a radiation shield, due to the high contamination of the trapped/absorbed ACPs.

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.

The HRS consists of the Cooling Tower System (CTS), with 4 air forced 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).

Releases from the CWS

Solid waste release

The main solid radwaste release from the CWS (namely from the CVCSs) are the mechanical filters and the spent ion exchange resins from the demineralisers with high contamination of the trapped/absorbed ACPs.

All these units will be routinely changed every year with an overall amount of about 12 m3/y with a T activity < 2 TBq/m3 and ACP activity < 0.3 GBq/m3.

Liquid waste release

After 10 y of operation in Deuterium/Tritium phase the T concentration in the 800 m3 of water of the FW/BLK and DIV/LI PHTSs will reach the value lower than 1.85 TBq/m3. The ACP contains will be negligible because trapped in the CVCS loops.

This water will be stored on site to the properly reprocessed before the final release to the environment.

The water in the secondary CCWS/1 will be periodically released according to the T limit concentration imposed to the French Local Authority (Prefecture).

Liquid and Gas release from the CTS

When the CTS will operate at full power (450 MW) the water evaporation rate will be about 200 kg/s. The water make up unit will correspondently provide 260 kg/s from the river Verdun because about 60 kg/s will be released as blow down to control the salt concentration in the loop and to prevent the growth of biologic species (i.e. algae).

The liquid effluents will be release in the river La Durance, after having performed the routine control of the main parameters, shown in Table I, in the storage basins (four each of 3000 m3) as authorized by the French Local Prefecture.

Parameter	Authorized limit	Max daily authorized limit	Periodicity of control
Total Flow rate effluent (m3/d)	4000 daily peak	3000 monthly average	continuous
PH	5.5 - 9		continuous
Max. outlet temperature (C)	30		continuous
Chlorates (mg/l)	200	450 (kg/d)	daily
Sulfates (mg/l)	700	1575 (kg/d)	daily
Phosphates (mg/l)	10	22.5 (kg/d)	daily
Fluorites (mg/l)	1	2.25 (kg/d)	daily
Tritium (MBq/m3)	10	22.5 (GBq/d)	daily
Total radionuclides (MBq/m3)	0.1	225 (MBq/d)	daily

Table I – Limit of authorized water release and chemical parameters

Conclusion

The ITER Cooling Water System is based on some Primary Heat transfer Systems (PHTS) and two closed intermediate Component Cooling Water Systems (CCWSs) that transfer the heat generated in the Plasma and in its auxiliary equipments to an open Heat Rejection System (HRS).

This organization permits a full control of the water coolant, its relevant contamination due to the neutron generated in the Plasma by DT reaction and the related effluent management.

In fact, the closed CCWSs represents second barriers against the possible release of contaminants, both in gaseous and liquid form, from the primary heat transfer nuclear systems to the environment.

The adoption of the Cooling Tower also permits the reduction of the water release in the river close to the site.