DESIGN FEATURES OF ITER COOLING WATER SYSTEMS TO MINIMIZE ENVIRONMENTAL IMPACTS

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INTRODUCTION

ITER is a joint international fusion facility which is being built in France to demonstrate the scientific and technological feasibility of fusion power. ITER will pave the way for the commercial exploitation of nuclear fusion to meet the ever increasing energy needs of mankind. Fusion power at ITER is generated using a Tokamak machine in which burning plasma inside the vacuum vessel at temperatures in excess of 150 million°C is confined by magnetic fields. The amount of heat energy generated from the Tokamak and the auxiliary systems are removed by the Cooling Water System (CWS). Cooling water system is designed to remove the total peak heat load of about 1100MW to the atmosphere by circulating approximately 25,000 m3 of water of diverse chemical specifications in multiple loops.

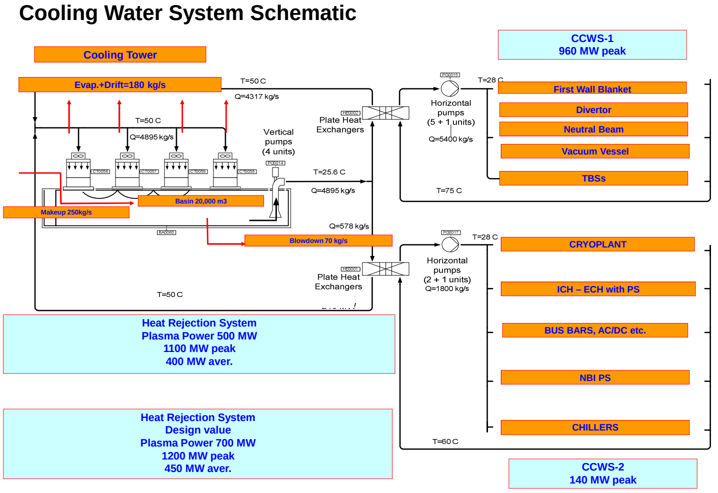
The design of the cooling water systems considers occupational health and safety, nuclear safety, radiation protection, and environmental protection requirements. Minimizing environmental impact is a major factor in demonstrating the viability of fusion energy as future energy source. This paper presents the features in the design of CWS for making it environmentally friendly.

ITER Cooling Water System

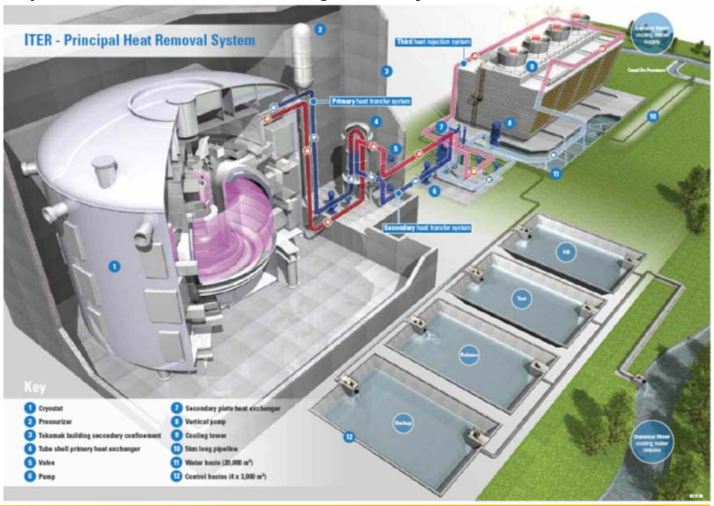
An effective heat removal system is extremely important for the safe and successful operation of fusion facility at ITER. The ITER Cooling Water System (CWS) consists of the Tokamak Cooling Water System (TCWS), the Component Cooling Water System (CCWS), the Chilled Water System (CHWS), and the Heat Rejection System (HRS). CCWS is further divided into CCWS-1 and CCWS-2; and CHWS into CHWS-H1 and CHWS-H2. All these are closed loop systems, except HRS which is an open loop system. Heat from all the loops, except CHWS-H1, is ultimately transferred to HRS and then rejected to the atmosphere through the forced draft Cooling Towers.

Tritium will be used as part of the fuelling for the fusion reaction. Tritium permeation through the plasma facing in-vessel components causes tritium contamination of the TCWS primary heat transfer loops. Neutron flux produced during fusion of deuterium and tritium will induce neutron activation of materials such as plasma facing components, impurities and corrosion products contained in the primary cooling water resulting in the production of activated corrosion products in cooling water. The main sources of radioactive contamination in TCWS include Tritium, Activated Corrosion Products (ACP), ^{14}C, ^{16}N and ^{17}N isotopes.

Cooling Water System Schematic



A pictorial view of ITER Cooling Water System

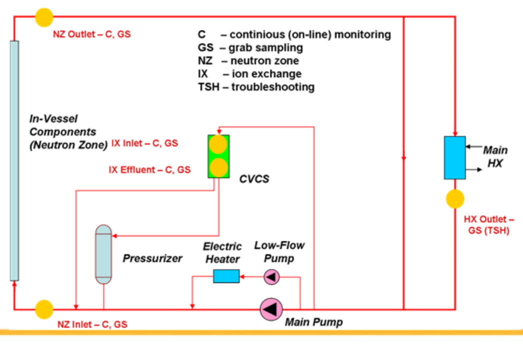


Main design features to minimize environmental impacts

The potential safety issues of TCWS and consequent impact on workers and environment is minimized by providing the following design features:

- Confinement of the radioactive substances
- Provision of decay heat removal capability in off-normal conditions
- Reduction of corrosion and fluid radioactivity by using CVCS(Chemical and Volume Control System)
- System design for very low leak rate
- Provision of an intermediate closed cooling loop between TCWS and HRS
- Provision of shielding to bring down the radiation field
- Injection of Hydrogen to suppress radiolysis
- Forced outgassing and recovery of tritium from in-vessel components
- Provision of large drain tanks for storage of contaminated water
- Avoiding usage of harmful chemicals for water treatment
  - The PHTSs has a safety role for the confinement of radioactive inventory due to ACP and tritium content in the water. TCWS pressure-retaining components are designated as safety important class (SIC) as they confine radioactive inventory. All of the TCWS equipment providing primary confinement is placed within the Tokamak Building to meet the confinement requirement.
  - The TCWS design includes a reliable means for removing the decay heat even in the case of off-normal accidental events.
  - Chemical specifications of water in TCWS loops are strictly controlled by the CVCS to minimize corrosion, thereby improving safety and reducing adverse environmental effects.

Typical TCWS cooling loop along with CVCS



- The TCWS is designed for very low leakage rate of ≤1 kg/hour to effectively confine the radioactive materials contained in the system and reduce the quantity of radioactive effluent that is to be processed and stored.
- The intermediate loop CCWS-1 is provided between PHTS and the open loop HRS to limit any inadvertent release of radioactive effluents to the environment. All TCWS heat exchangers are monitored for leakage and the leaky heat exchanger is isolated promptly on detection of leak.
- As the ACPs and other impurities get collected in the ion exchanger and filter units the radiation field around them could go high. Ion exchanger and filter units are given radiation shielding to bring down the radiation field to as low as reasonably achievable.
- Water undergoes radiolysis due to the effect of nuclear radiation. Radiolysis of water causes the oxidation potential to rise and it enhances metallic corrosion, with a corresponding increase in build-up of gamma field from transport of activated corrosion products (ACPs). Addition of hydrogen to the PHTS loops will be done to suppress radiolysis.
- Controlling the tritium inventories and reducing its releases is achieved by forced outgassing and recovering tritium from in-vessel components by water baking at 240°C and gas baking of divertor at 350°C.
- Three drain tanks having total volume of about 630m^3 are designated for normal operation and are used for the storage of coolant during maintenance and inspection. Two drain tanks having total volume of about 460m^3 are designated as Safety Drain Tanks (SDT) for safety operation to store the inventory of water caused from the design basis loss of coolant accident of the PHTS that results in a leak into the vacuum vessel (VV).
- Chemicals used for water treatment purposes are carefully chosen to minimize the impact on the environmental media, i.e. the Durance River. Strict control of the blow down water quality is carried out to meet the discharge limits specified by authorities of Marseille prefecture.

Hazards assessment

A preliminary hazards assessment was performed for a better understanding of the hazards, initiating events, and defense in-depth mechanisms associated with the TCWS. All hazards except that of radiological were screened out as either not being large enough to pose a significant risk to workers, the public and/or the environment, or else they were commonly found in industry and covered by existing industrial safety regulations or standards.

CONCLUSION

The design of TCWS, CCWS, CHWs and HRS incorporates features for reducing the hazards by minimizing leakages and effluents (both radioactive and non-radioactive), curtailing the usage of chemicals, maintaining water chemistry suitable for reducing corrosion etc. Concerns about radiation protection, effluent discharges and environment impact for ITER can be minimized by these design features. The release responses of ITER plant were analyzed for various operational scenarios and appear well within the set project guidelines even with elevated release assumptions.

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