

# THE ITER HEAT REJECTION CHALLENGE

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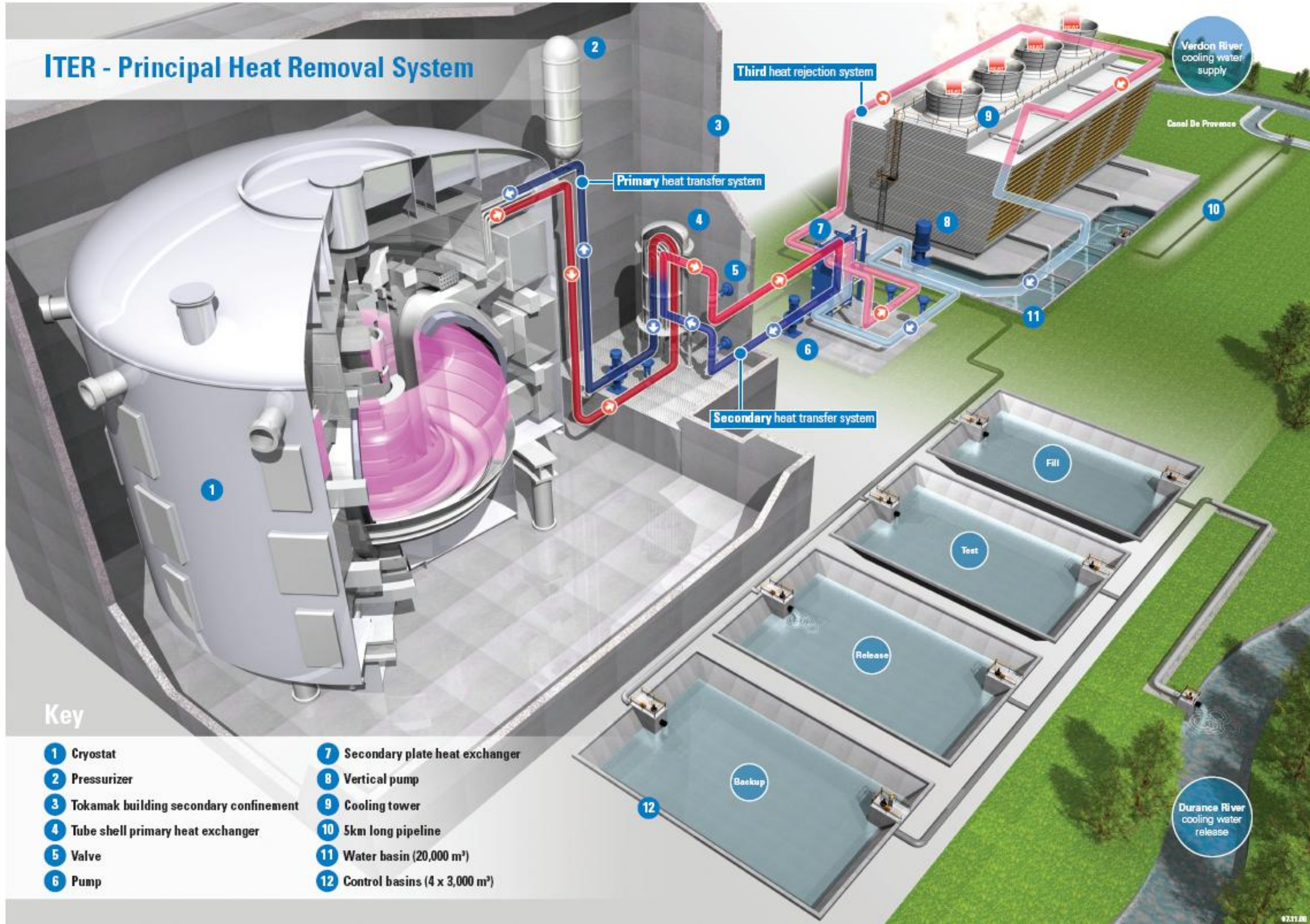


Figure 1 - Heat Transfer from the Tokamak to the Cooling Towers

## THE HEAT REJECTION SYSTEM

The ITER Heat Rejection System receives the heat produced by the Tokamak and the plant auxiliary systems and rejects it to the atmosphere using mechanical induced-draft “wet” cooling towers. Such cooling towers were chosen for ITER heat rejection since they are cost-effective.

The relationship of the cooling water systems that transfer heat from the Tokamak to the cooling towers is illustrated in Figure 1. Figure 2 is a conceptual schematic of the 2010 baseline design, showing how the Component Cooling Water System collects heat produced by the Tokamak and the many auxiliary systems and transfers it to the HRS.

## THE CHALLENGE

ITER will experience about 30,000 plasma pulse cycles over an operating life of 20 years. Each pulse cycle consists of a “burn” phase and a “dwell” phase. During the burn phase, large quantities of heat are generated in the Tokamak and transferred via the TCWS and CCWS to the HRS. During the dwell phase, the amount of heat being produced decreases abruptly to about 10% of the amount produced during the burn phase. In contrast with a fission reactor, the amount of decay heat is very small. Figure 3 illustrates the rates of heat generation during the burn and dwell phases of the pulse cycle for the principal modes of ITER operation. The basic challenge then, is how best to meet the heat rejection needs while minimizing the cost and footprint of the cooling towers.

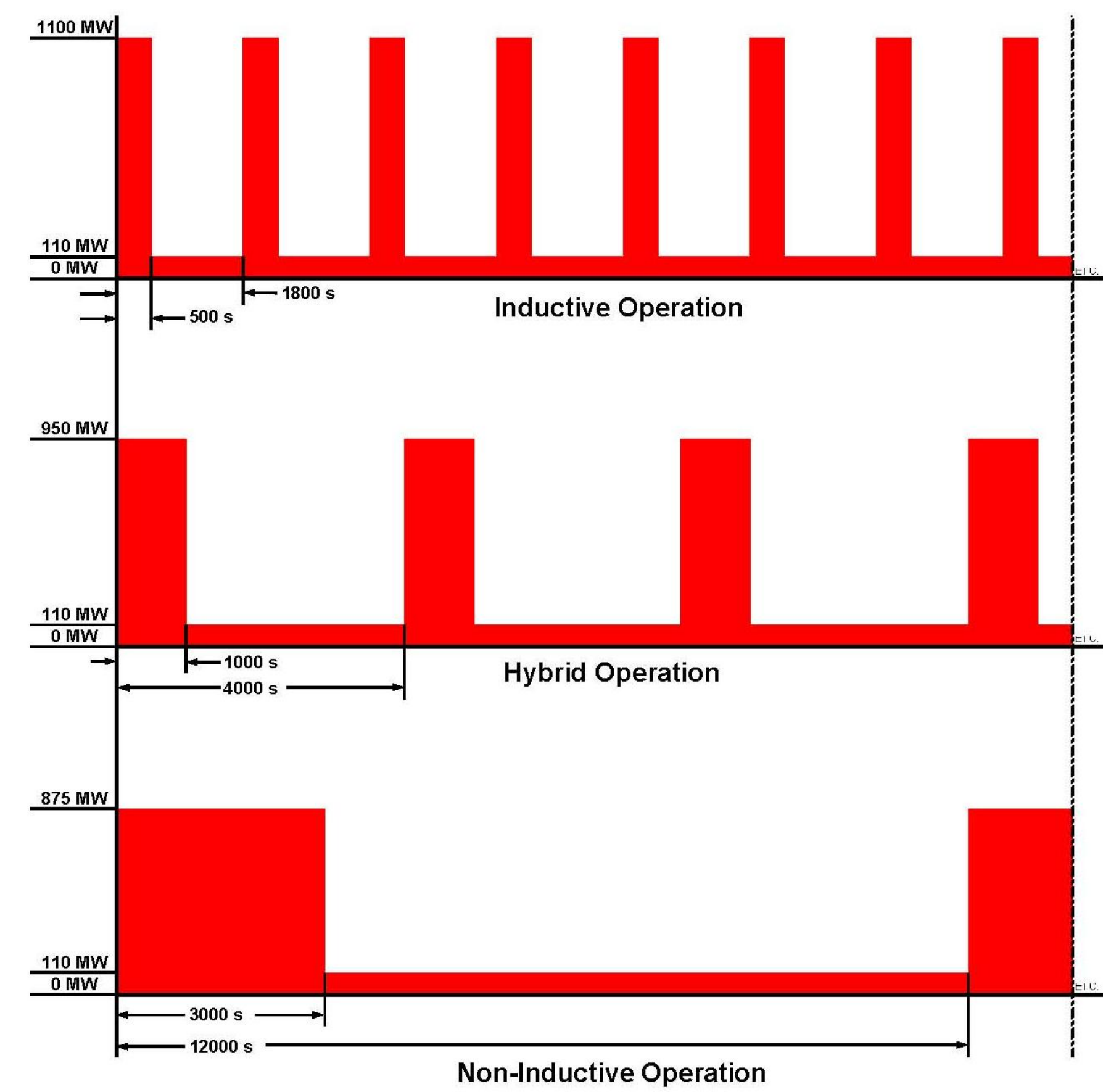


Figure 3 - Heat Rejection Profiles for ITER Reference Plasma Scenarios

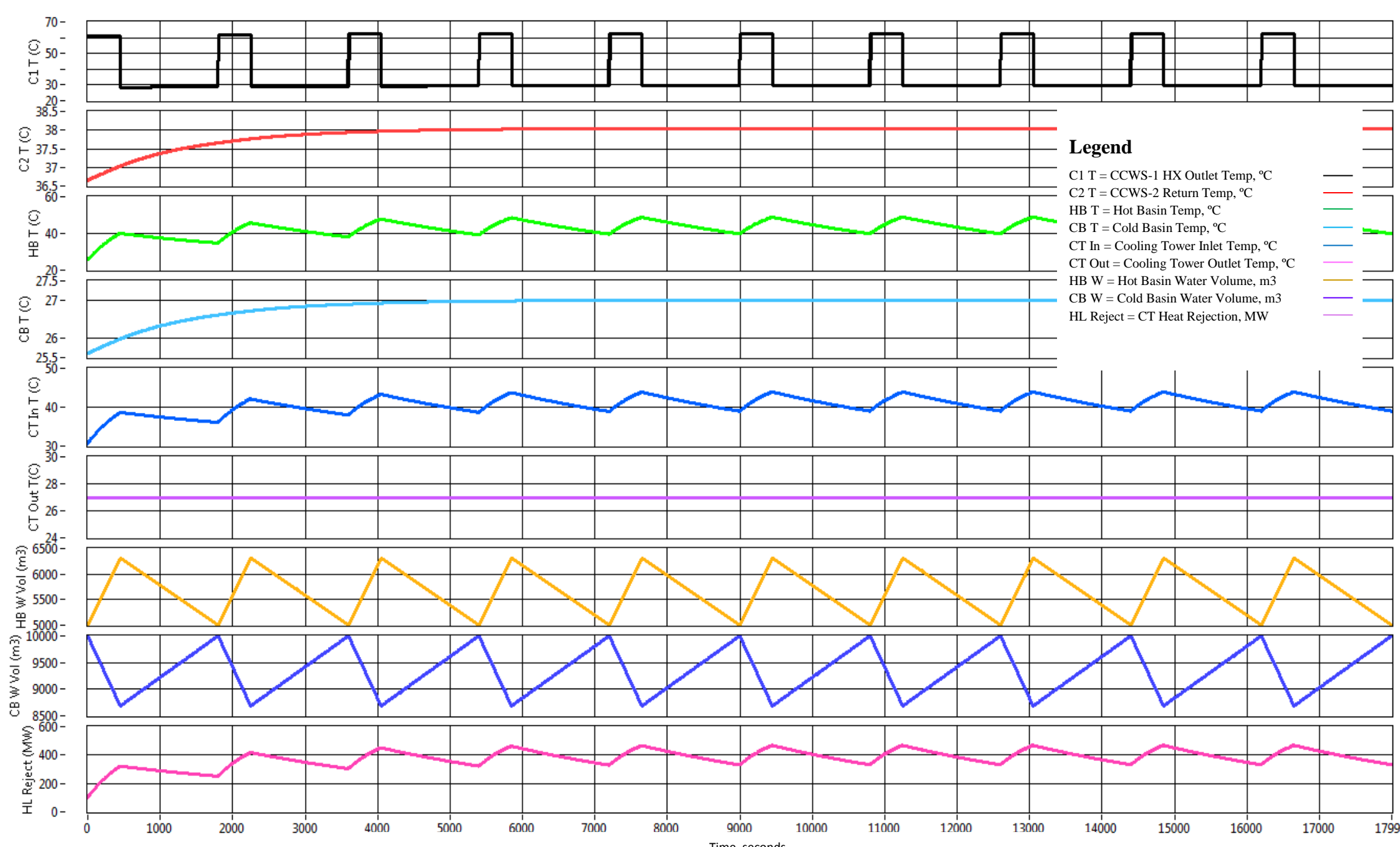


Figure 7 - Simulation Software Results for Proposed Design - Inductive Operation Scenario

## Principles of Cooling Tower Operation

The heat produced by ITER is ultimately transferred to the atmosphere by the evaporation of water, taking advantage of water's large latent heat of vaporization to cool the remaining water. Evaporation of water is facilitated by increasing the surface area of the water (droplet size or film area), increasing the volume of air exposed to the water (cooling tower area and fan speed), and increasing the time in which the water is in contact with the air (cooling tower height). Figure 4 illustrates a conceptual cooling tower of the type proposed to be used for ITER, and associated nomenclature.

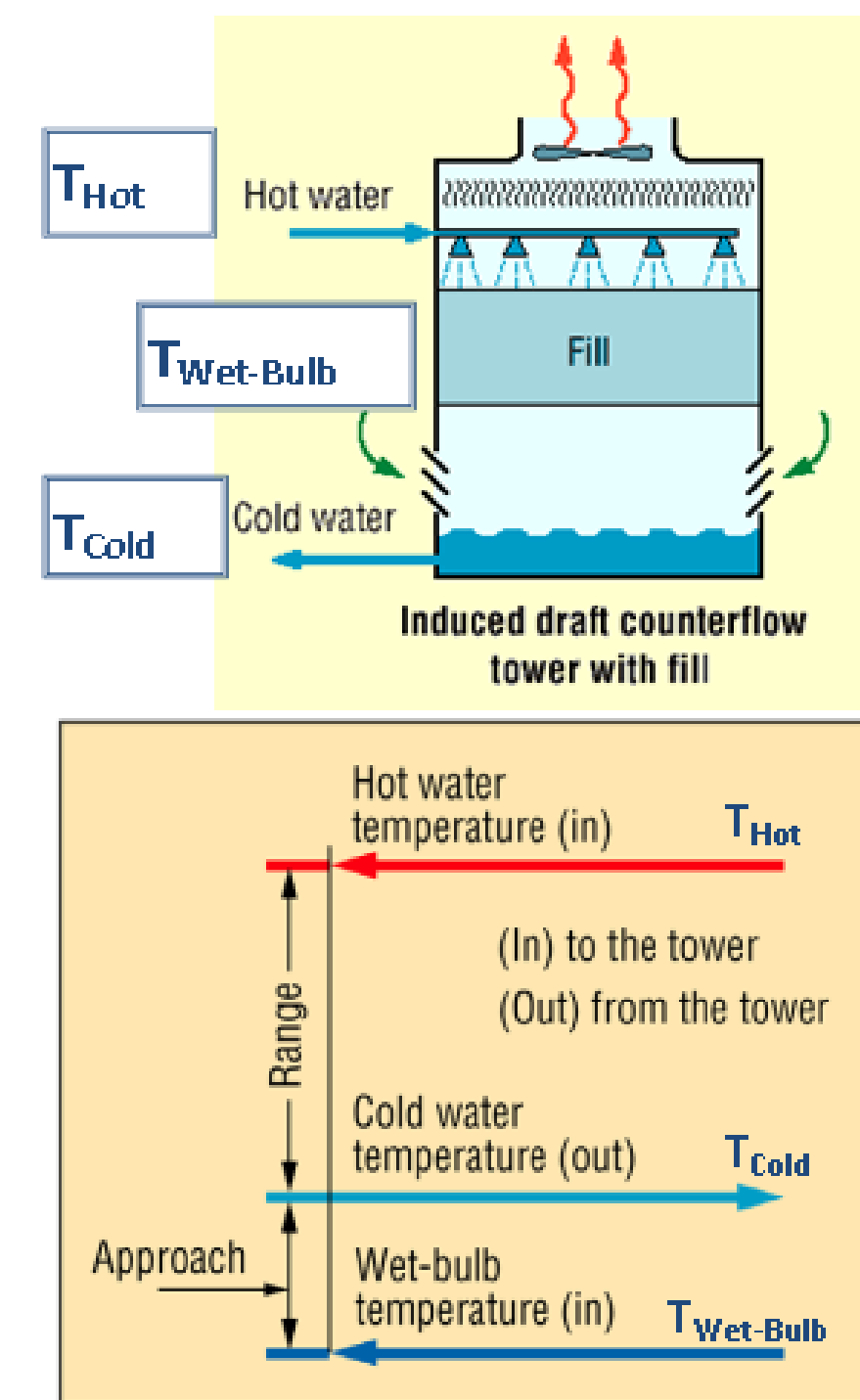


Figure 4 - Cooling Tower Nomenclature

## Objectives for Reducing Cooling Tower Size

- 1) Reduce peak heat transfer rate by averaging the heat load over the pulse cycle (e.g. store the hot water and process it during the full pulse cycle)
- 2) Increase cooling tower approach temperature (e.g., by reducing design wet-bulb temperature or by increasing basin temperature)
- 3) Avoid operation with very high and very low cooling tower ranges (e.g. by increasing the range during the dwell by minimizing cold water dilution)

## THE SOLUTION

Following evaluation of many alternatives ITER-India and their consultants, in consultation with the ITER Organization, proposed a design solution that includes features that meet all three objectives described above. The principal features are:

**Feature #1:** Addition of a hot basin and recirculation pumps. The area of the cooling tower basin is enlarged and partitioned into a hot basin and a cold basin. New vertical pumps take suction from the hot basin and discharge to the cooling towers at a constant rate. The cooled water collects in the cold basin.

**Feature #2:** Introduction of variable speed drives for the pumps which circulate water from the cold basin to the hot basin via the CCWS-1 heat exchangers (removing heat generated in the Tokamak).

**Feature #3:** Increased cooling tower approach, achieved by increasing peak summertime basin temperature

The revised configuration of CCWS and HRS incorporating these proposed design features is shown in Figure 6. Figure 7 shows the variation in parameters over repeated plasma pulse cycles, for inductive operation.

**Abstract:** ITER is an international fusion facility 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 at temperatures of 150,000,000 °C is confined within a vacuum vessel by magnetic fields. The enormous amount of heat generated by the Tokamak and its auxiliary systems is removed by the cooling water systems, consisting of the Tokamak Cooling Water System (TCWS), the Component Cooling Water System (CCWS), the Chilled Water System (CHWS), and the Heat Rejection System (HRS). These systems are designed to remove an initial peak heat load of about 1100MW.

ITER is an experimental facility that will operate a cyclical fashion. High levels of fusion power will be generated during repeated plasma pulses with specified durations. Heat produced by the fusion reaction will not be used to generate electricity, but will be rejected to the environment. The HRS rejects heat from the Tokamak and auxiliary systems to the atmosphere using mechanical forced-draft cooling towers.

The cyclical nature of ITER operations presents distinct challenges to the design of the HRS which must reject normal facility heat loads plus large, intermittent heat loads from Tokamak pulse operations, while maintaining stable and predictable cooling tower basin water temperatures to meet the needs of cooling water system clients. A complicating factor is the need to provide high flow rates, with correspondingly low differential temperatures, to many clients. This paper explores these challenges to the HRS design and describes the selected solution.

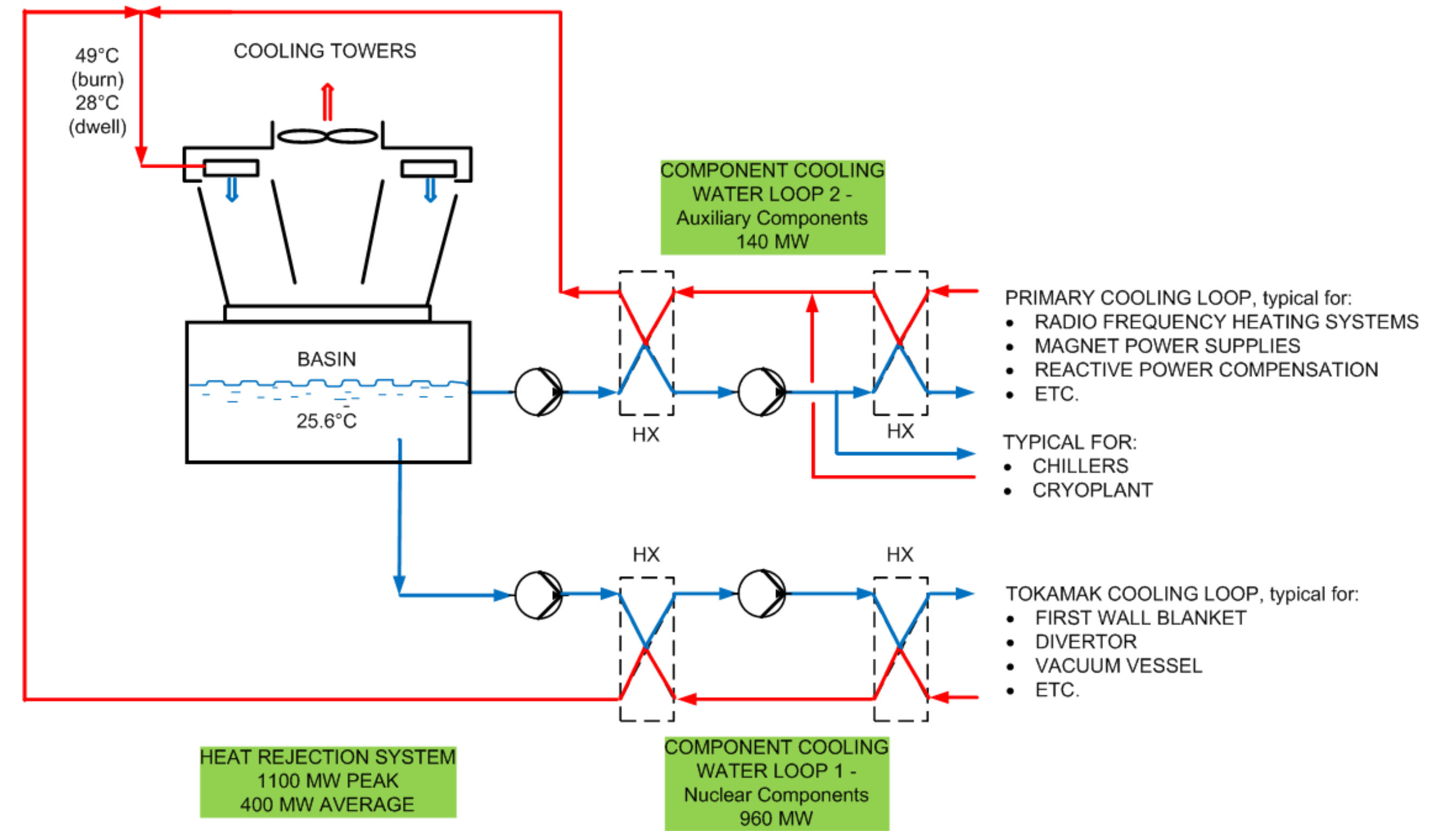


Figure 2 - ITER Heat Rejection and Component Cooling Water Systems Configuration - 2010

## General principles for cooling tower sizing:

Principle #1: Cooling tower size increases as the total rate of heat transfer increases

Principle #2: Cooling tower size increases as approach decreases (see Figure 5)

Principle #3: Cooling tower size increases as range decreases

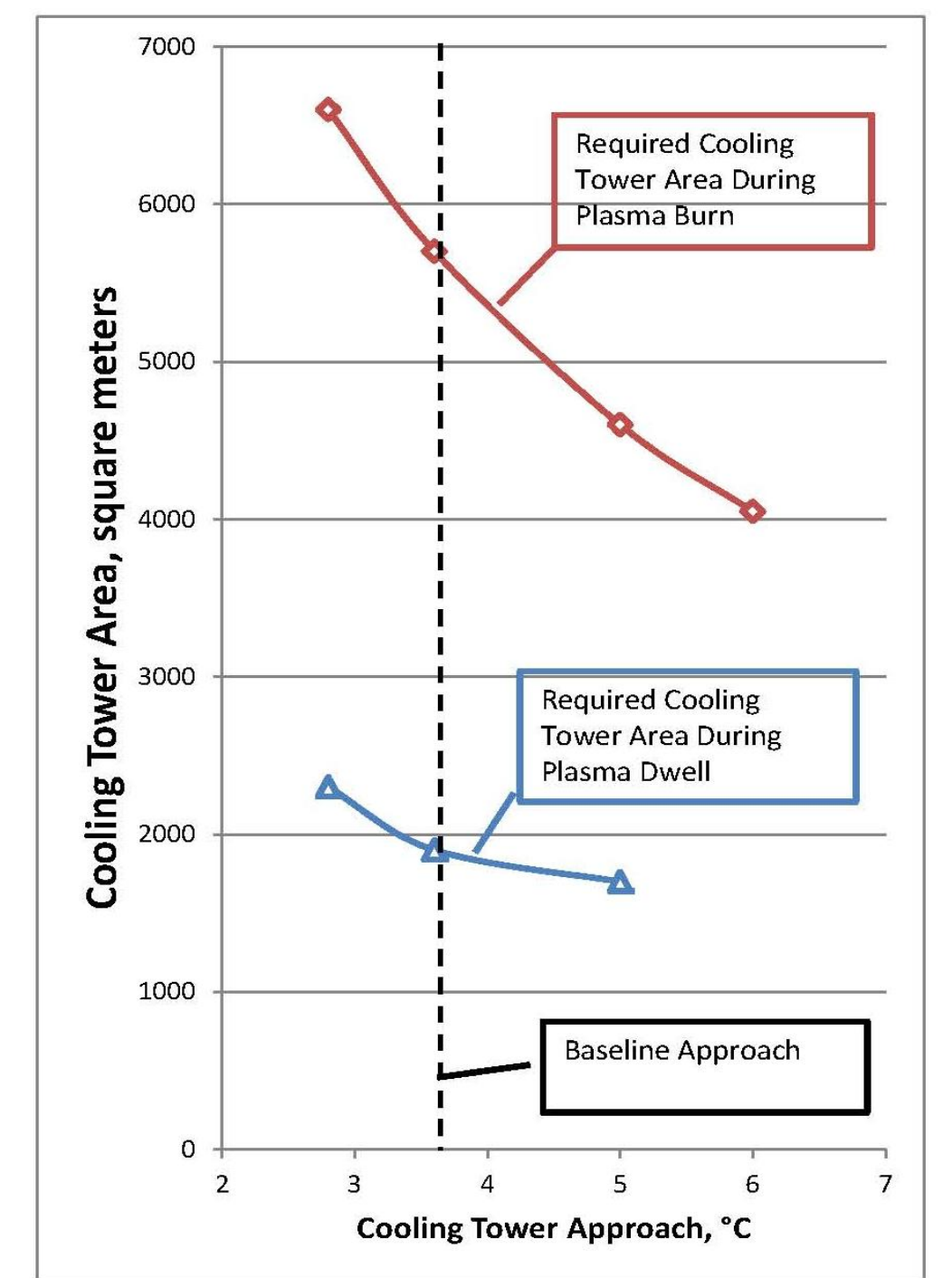


Figure 5 - Cooling Tower Area vs. Approach

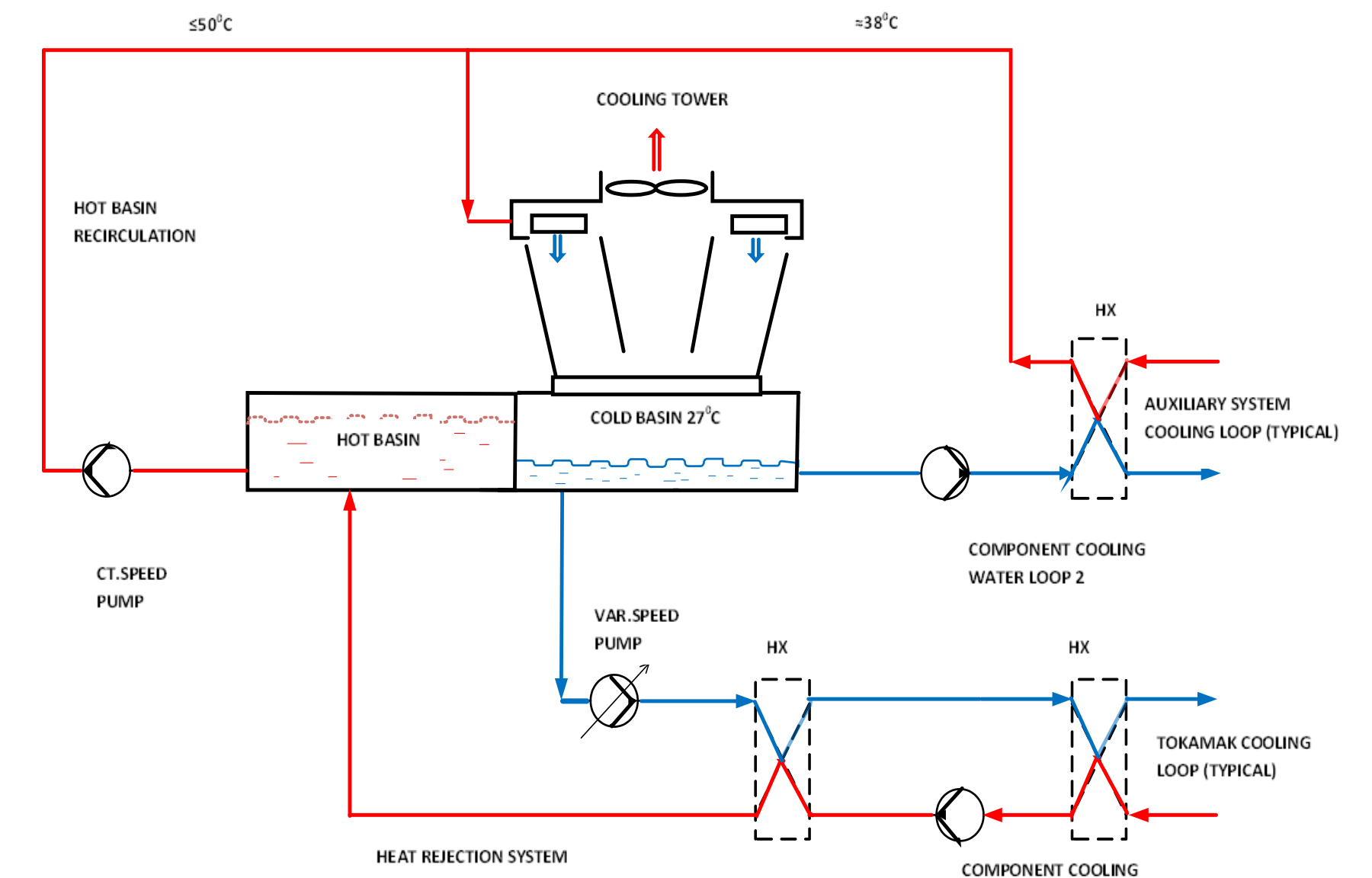


Figure 6 - Proposed Configuration for CCWS and HRS

## CONCLUSION

Actual cooling tower size configuration will be determined by the cooling tower designer. But the results of these proposed design changes are expected to result in a total cooling tower area about 50% less than might otherwise be required.