Overview of Cooling Water System for the KSTAR 1st Plasma Experiment

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1. Introduction

The KSTAR cooling water system (CWS) consists of a primary cooling water system (PCWS), a secondary cooling water system (SCWS), and a de-mineralizing & de-ionized water system (DIWS). The PCWS cooling loops have been made for the poloidal field (PF) and toroidal field (TF) magnet power supplies (MPS), vacuum vessel (VV), electron cyclotron heating (ECH), ion cyclotron heating (ICRH), vacuum pumps, diagnostics, helium facility, etc. The CWS had been done individual commissioning of each system to confirm the design specifications by the end of 2006 and had gradually begun operation for the KSTAR ancillary devices by March 2008.

2. Design Conditions

The operation load of the KSTAR experimental equipments is grouped into the categories of pulsed loads and continuous loads [1]. The continuous loads are thermal loads during the steady state experimental time and the pulsed loads are the thermal loads only during plasma shots. Therefore, the cooling load of a pulsed load is calculated not as a peak load but as an average load taking account of the duty factor, while that of a continuous load is calculated as a total load. Figure 1 shows the temperature change of cooling water for a pulsed load [1].

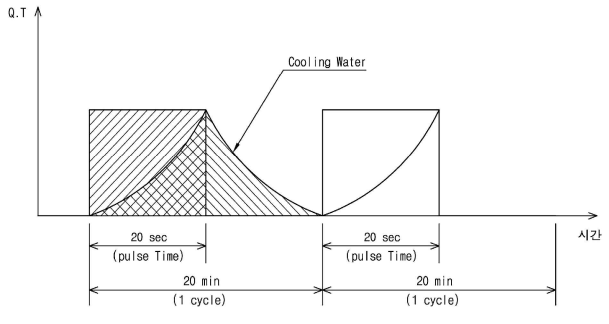

Fig. 1. Temperature Change of Cooling Water for a Pulsed Load

The calculation of the average load is influenced by large storage tanks which reduce the required capacity of the chillers and cooling towers. The pipe material of the PCWS is selected to be STS316L to maintain the quality of DI cooling water, while that of the SCWS is selected to be STS304 [1]. The selection of pipe diameter in the CWS has to consider in economical efficiency, the noise due to the velocity of the moving fluid, and is concerned with the venting speed of bubbles in cooling water. The velocity must be high enough that the bubbles are carried to a vent chamber where they can be removed. We chose the recommended velocity of about 3 m/s, and a frictional loss of about 30mmAq/m [1].

3. System Description

The CWS goals are to effectively cool the operating KSTAR which produces a great deal of heat and to heat the vacuum vessel for cleaning in-vessel components (IVC) during the maintenance periods of KSTAR. The PCWS loops circulate the DI water and the SCWS loops circulate the treated water which is the city water. The PCWS loops transfer the heat from experimental equipments to heat exchangers; the SCWS loops exhaust the heat through the chiller and cooling tower from heat exchangers to the atmosphere. For minimizing the operating cost, the CWS has two-step heat exchangers, tower water is circulated in the pre-cooler and chilled water is circulated in the cooler, respectively. Figure 2 shows a diagram of the cooling water system [1].

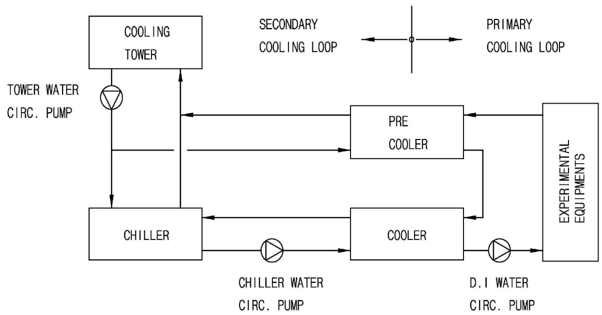

Fig. 2. Diagram of the Cooling Water System

The PCWS loops are closed loops, and each loop consists of the following mechanical equipments; a DI water storage tank, circulation pumps, heat exchangers, ultra violet lamps, a electric heater, a DI water polisher system and automatic valves, etc. The SCWS loops are divided into chilled water loops and tower water loops. The former is a closed loop and the latter is an opened loop. The SCWS consists of chillers, cooling towers, chilled water circulation pumps, tower water circulation pumps, an expansion tank, water filters, etc. The helium refrigeration system which consists of a warm compressor station (WCS), a cold box, distribution boxes and helium storage is a facility for cooling down the KSTAR superconducting coils to extremely low temperature [2]. The tower water is circulated through the WCS; the DI water is circulated through the cold box and distribution boxes. The gaseous nitrogen (GN_2)

pressurizing system functions are to prevent air from coming in contact with the DI water in the storage tanks in order to maintain the water quality, and maintain the static pressure of the system loops. The object of the heating systems is to remove impurities from the surface of the VV and the systems are categorized by the type of fluid: a super heated (400℃) GN_2 baking system and a hot water (130℃) baking system [1]. The DIWS consists of a DI water make-up system and a DI water polishing system. The former is a system to produce the DI water and the latter is a system to maintain the quality of the DI water. The main parameters of the CWS for the experimental equipment for the KSTAR first plasma are summarized in table I [1].

Table I: parameters of the PCWS for the KSTAR 1st Plasma

Equipment	T_{in} (℃)	Flow-rate (ℓ/ s)	P_{in} (kg/㎠)	Resistivity (MΩ-㎝)
vacuum pump diagnostics, etc	≤ 25	≥ 1.95	≤ 5	≥ 1
Vacuum Vessel	≤ 35	≥ 26.5	≤ 4	≥ 1
ECH	≤ 25	≥ 20.8	≤ 10.3	≥ 1
ICRH	≤ 25	≥ 25	≤ 6	≥ 1
MPS TF	≤ 30	≥ 5.5	≤ 8	≥ 5
MPS PF	≤ 30	≥ 17.96	≤ 8	≥ 3
WCS of HRS	≤ 32	≥ 539.4	≤ 2.4	-

4. Commissioning Results

The KSTAR 1st plasma tests produced a plasma current of more than 100 kA with a pulse of duration of more than 100 ms at a magnetic field of 1.5 Tesla [3].

Cooling water was used to cool the vacuum pumps for vacuum of the vacuum vessel, the cryostat, the current lead box, the distribution boxes, and the turbines and cold compressors of the cold box. During operation, the temperature change (ΔT) of the cooling water was about 3 ℃.

The ECH system is composed of an 84-GHz, 500-Kw gyrotron, a transmission waveguide, and a launcher [4]. Although it was operated at full power of 500 kW and a full pulse length of 2s, the ΔT of the cooling water was hardly changed. The ICRH system consists of a transmitter, a transmission line, a matching device, an antenna. It was used for helium discharge cleaning to clean the VV walls [3]. The ΔT of the cooling water was about 1.5 ℃ at a power of about 50 kW and pulse of duration of 300ms.

The TF MPS consists of AC/DC converters, a filter, a slow discharge circuit (SDC), a quench protector (QP), and a direct current disconnection switch (DCDS) [5]. The insulated gate bipolar transistors (IGBT) and transformers of AC/DC converters, and the bus-bars outside the panel of the TF MPS are water cooled [6]. The final system commissioning of the CWS for the TF MPS with 15 kA in a superconducting (SC) load was performed, and the inlet temperature and ΔT were 27.8 ℃ and 3.3 ℃, respectively, when the cooling load was 76 kW [7]. The PF MPS consists of 7 independent power supplies to apply current to the 7 pairs of PF SC coils up to 20 or 25 kA [5]. Each PF MPS is composed of a converter unit, a QP, a quench protector resistor (QPR), a blip resistor insertion system (BRIS), a DCDS, and DC bus-bars [5]. The IGBTs and converter transformers are cooled by water, while the DC bus-bars in the PF MPS are cooled by air [7]. The maximum current of the PF MPS was 3 kA, and the ΔT was very small change in the 1st plasma experiment.

The design capacity of the HRS is 9 kW at 4.5 K, and its WCS had a two stages oil flood screw compressor with a total flow rate of 1,040g/s at 22bar [2]. The helium and the oil heat exchangers of the compressors are cooled by the SCWS and the ΔT and pressure change(ΔP) of their cooling water were 5 ℃ and 0.6 kg/㎠, respectively.

5. Conclusions

The CWS was operated in the integrated commissioning phase and performed with no mechanical problems in the 1st plasma experiment period. Because the KSTAR 1st plasma operation period from the viewpoint of the CWS operation had a small heat load in the cooling water of the experimental devices, the ΔT of the cooling water was not large, so we could confirm the performance of only parts of the CWS loops. The CWS is being prepared for the KSTAR 2nd campaign. The 2nd campaign will be operated with a TF MPS current of 40 kA and the PF MPS currents increased for single null (SN) operation. The performance of the CWS with upgraded monitoring system is expected to be confirmed.

ACKNOWLEDGEMENT

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