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STUDY OF PF-RING INFRASTRUCTURE IMPROVEMENTS USING TEMPERATURE MEASUREMENTS IN THE RING TUNNEL

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Abstract

Temperature measurements have been performed in the PF-ring tunnel in order to understand the infrastructure performance and the temperature stability toward the PF upgrade project, where better beam stability will be required. Based on the temperature measurements, possible improvements of the PF-ring infrastructure such as the air-conditioning and cooling-water systems have been studied to enhance the temperature stability in the ring tunnel. In this paper, we present results of the temperature measurements and a proposal of the infrastructure improvements.

INTRODUCTION

Figure 1 shows the layout of the PF Light Source Building. The PF ring is placed in the ring tunnel of the building. Temperature measurements have been performed in the ring tunnel for more than two years in order to understand the infrastructure performance and the temperature stability toward the PF upgrade project [1], which is planned to reduce the emittance of the PF ring and to improve the beam stability. Based on the temperature measurements, possible improvements of the PF-ring infrastructure have been studied. In this paper, we describe the temperature measurement results and the PF-ring infrastructure improvements.

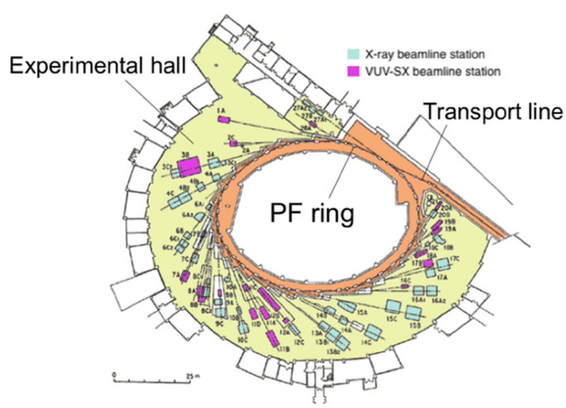

Figure 1: Layout of the PF Light Source Building. The orange area shows the tunnel of the PF ring including a part of the beam transport line from the injector linac and the yellow area the experimental hall with SR beamlines.

PF-RING INFRASTRUCTURE

Building

The PF Light Source Building that encloses the PF ring and the experimental hall is distorted by thermal stress due to the solar irradiation and surrounding atmosphere [2]. As a result, the floor displacement of the ring tunnel and the experimental hall generated by the thermal stress induces the position movement of the electron and SR beams. As shown in Fig. 2, the thermal insulator almost covers the outside roof of the building to reduce the thermal stress, but the injection area (a red frame area in Fig. 2) has no thermal insulator for a carry-in route.

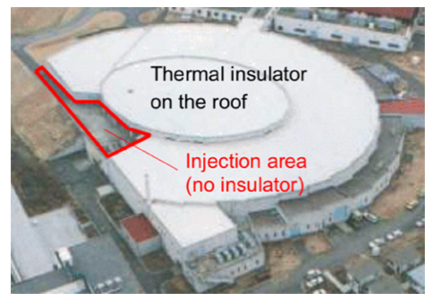

Figure 2: Photograph of the PF Light Source Building. A red frame area is the injection area including a part of the transport line and has no thermal insulator on the roof.

Airconditioning Systems

There are two air-conditioning (AC) systems AC-3 and 4 for stabilizing the temperature in the ring tunnel as shown in Fig. 3. Temperatures in the tunnel are monitored with five temperature sensors on the wall and two of them are used for the feedback (FB) control. It is noted that the AC air duct of the injector area is narrow and the number of wind outlets is small compared to the other areas.

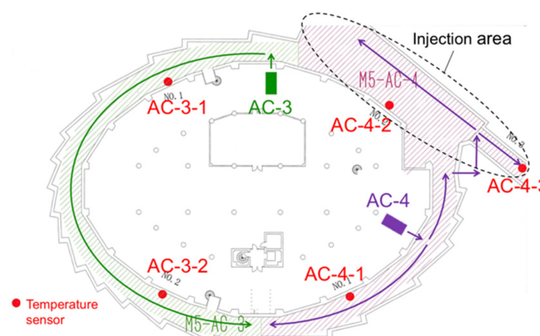

Figure 3: Layout of two air-conditioning systems (AC-3 and AC-4) for the PF-ring tunnel and the airflow directions in the air ducts. Five temperature sensors (two for AC-3 and three for AC-4). One sensor for each air-conditioner is used for the temperature FB control.

Cooling Water Systems

Two cooling-water systems B and C work for cooling magnets and vacuum ducts and RF cavities and RF sources respectively, as shown in Fig. 4. The cold water is

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transported to the PF cooling-water systems from a different building for heat exchange.

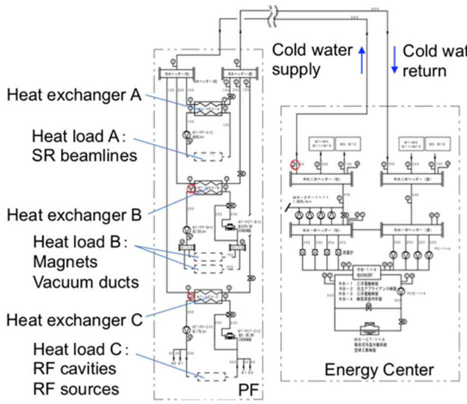

Figure 4: Schematic view of the cooling-water systems for the PF ring.

TEMPERATURE MEASUREMENTS

We started systematic temperature measurements in the ring tunnel from 2018 in order to understand the infrastructure performance and the temperature stability of the ring tunnel toward the PF upgrade project. In this section, results of the temperature measurements are reported.

Measurements from May to July 2018

Before user operation of May to July 2018, eight Pt thermometers were set at six ring components (magnets and supports) and two AC wind outlets on the tunnel ceiling as shown in Fig. 5. The AC-3-2 and AC-4-1 sensors were chosen as the FB sensors of AC-3 and AC-4 and the setting temperature is 24 ºC.

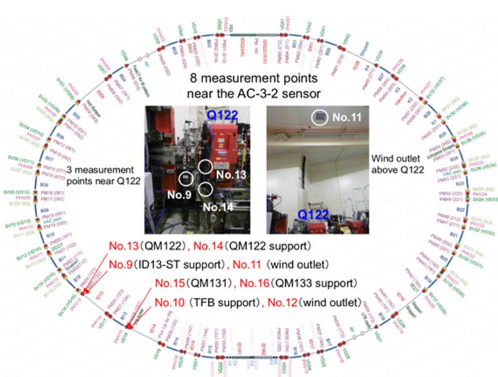

Figure 5: Eight Pt thermometers in the ring tunnel for temperature measurement of two magnets, four supports and two AC-3 wind outlets near the AC-3-2 sensor.

Figure 6 shows a time chart of the measured temperatures with the beam current in the PF-ring operation of May to July 2018. Main results from the temperature measurement are as follows.

- Temperatures at the two AC-3 wind outlets continued to increase with those of the six ring components after they initially decreased to the minimum, because the AC-3 cooling-water valve became fully open and the AC-3 cooling power reached the upper limit.
- Temperatures of AC-4-2 and AC-4-3 greatly drifted and varied compared to those of the other sensors. The AC cooling power in the injection area was insufficient.
- Temperatures of the cooling-water systems B and C significantly varied with the outside air temperature in July, while temperature of the cold-water supply was almost constant. Performances of the cooling-water systems became insufficient in July 2018.

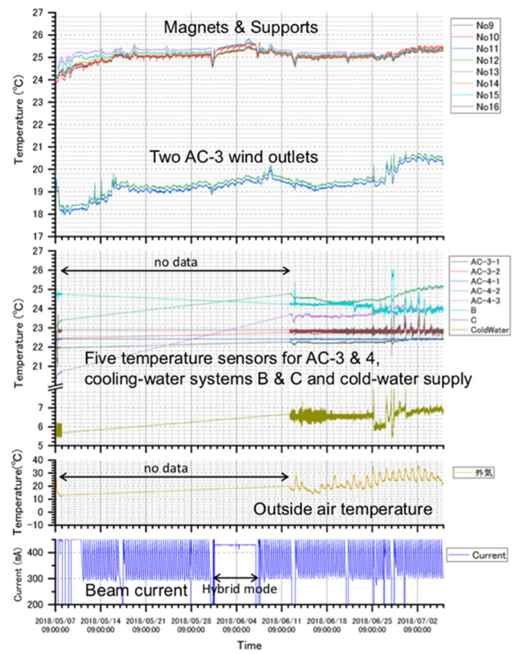

Figure 6: Temperature measurements from May to July 2018 with eight Pt thermometers.

Measurements from February to March 2019

From October 2018, the Pt thermometers were increased to twelve in number and more uniformly distributed along the ring as shown in Fig. 7. Before the user operation, the AC-4 FB sensor was changed to AC-4-2 for temperature stabilization of the injection area, but the AC-4-1 temperature drastically varied, probably because the airflow rate in the injector area is very low. Therefore, we undid the change of the FB sensor of AC-4.

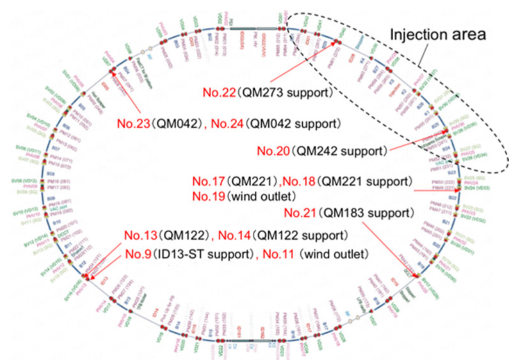

Figure 7: Twelve Pt thermometers for temperature measurement of three magnets and seven supports and AC-3 and AC-4 wind outlets.

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Figure 8 shows an example of the temperature measurement with the twelve thermometers in February to March 2019. Main results of the temperature measurement are as follows.

- Temperature drifts of the two magnet supports (No.20 and 22) in the injector area were relatively large compared to those of the ring components in the other areas and correlated with the AC-4-2 temperature.
- Temperature at the AC-4 wind outlet was well controlled to stabilize temperatures of the ring components, while temperature at the AC-3 wind outlet still showed an abnormal behavior because the AC-3 cooling-water flow rate reached the upper limit.

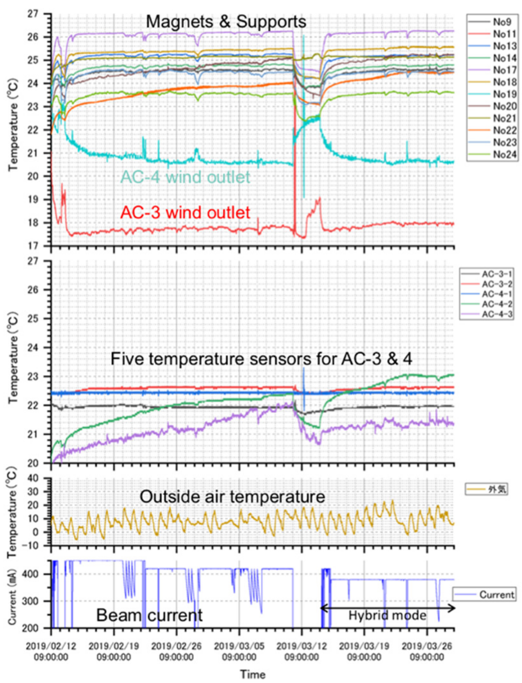

Figure 8: Temperature measurements from February to March 2019 with twelve Pt thermometers.

Measurements from February to March 2020

From May 2019, the AC-3 FB sensor was changed from AC-3-2 to AC-3-1 to keep a longer distance between the AC-3 and AC-4 FB sensors. Figure 9 shows an example of temperature measurement in February to March 2020 after the AC-3 FB sensor change. Main results of the temperature measurement are as follows.

- Temperatures of the two magnet supports in the injection area still significantly varied and correlated with the AC-4-2 temperature.
- Temperatures of AC-4-2 and AC-4-3 still greatly drifted compared to those of the other sensors.
- The wind-outlet temperature of AC-3 became well controlled by changing the AC-3 FB sensor to AC-3-1 and very similar to that of AC-4, because the cooling-water flow rate of AC-3 was kept below the upper limit.

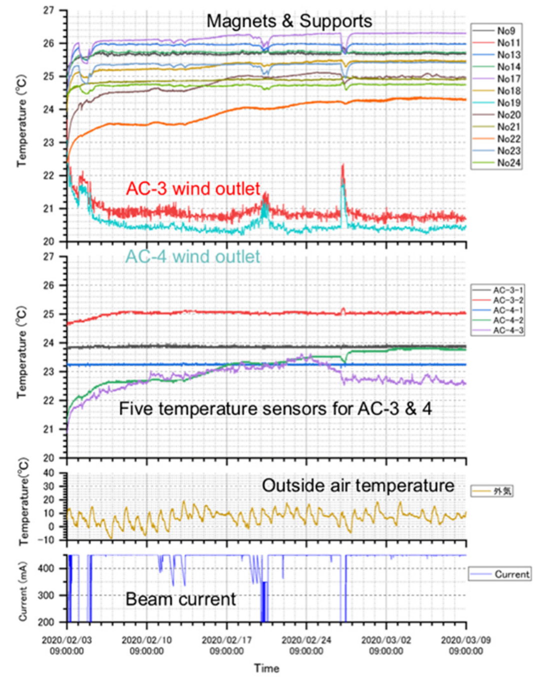

Figure 9: Temperature measurements from February to March 2020 with twelve Pt thermometers.

INFRASTRUCTURE IMPROVEMENTS

In the injection area, temperatures of the ring components drifted and varied greatly compared to those of the other tunnel areas, because the AC airflow rate is relatively very low and the injection area is more sensitive to the outside air temperature and the solar irradiation. Furthermore, temperatures of the cooling-water systems significantly varied with the outside air temperature in the hot days.

We are proposing the following improvements of the air-conditioning and cooling-water systems in order to stabilize temperatures of the ring tunnel and beam orbits toward the PF upgrade project.

(1) Increase of the AC-4 airflow rate in the injection area by increasing the AC duct size from 400 × 250 to 450 × 400 mm^2 or larger and the number of the wind outlets from 4 to 8 or more.
(2) Thermal shielding of the injection area by heat-shield painting of the outside roof and wall of the injection area and/or heat-insulation by glass-wool boards on the inside wall and ceiling of the injection area.
(3) FB control of AC-3 and AC-4 by averaged temperature of the multiple sensors.
(4) Increase of setting temperatures for AC-3 and AC-4 from 24 to 25 ºC or higher.
(5) Upgrade of the plate heat exchangers in the cooling-water systems with increase of the cooling-water pipe size.

Some experimental study may be needed for (3) and (4) to check effects on the temperature stabilization of the ring tunnel.

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