Hoshino Resorts
Bandaisan Onsen Hotel

**March 2025**

# Report

**Hoshino Resorts Bandaisan Onsen Hotel**
**Verification of the Heat-Shielding Effect of the Heat-Shielding / Thermal-Insulating Film Air**

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# Verification of the Heat-Shielding Effect of the Colorless Transparent Heat-Shielding / Thermal-Insulating Film “Air”

## [Objective]
To reduce cooling load during the summer season, the performance of the “Air” film was evaluated.

## [Overview]
The power consumption was measured during periods when the Air film was applied to the south-facing restaurant windows of Hoshino Resorts Bandaisan Onsen Hotel and during periods when it was not applied, in order to verify the performance of the “Air” film.

## [Results]

| | Average Outdoor Temperature (℃) | Average Sunlight Duration (h) | Average Temperature 1 cm from Window (℃)): Reference | Average Air Conditioner Outlet Temperature (Window Side) (℃) | Temperature Difference between Average Air Conditioner Outlet Temperature (Window Side) and without Air Film (℃) | Air Conditioner Operating Time (h) | Air Conditioner Operating Time Reduction Rate (%) “(①-②) / ① × 100” |
|---|---|---|---|---|---|---|---|
| ①Without Air Film | **18.9** | **3.2** | **26.0** | **16.1** | | **325.6** | |
| ②With Air Film | **19.2** | **2.4** | **25.7** | **18.1** | **7.6** | **249.5** | **23.4** |
| ③After Correction or Corrected (depending on context) | **19.2** | **2.4** | **26.1** | **18.5** | **7.2** | **234.3** | **28.1** |

It was confirmed that applying the “Air” film to the windows reduced summer power consumption by approximately 28.1%.

## [Conclusion]
Application of the “Air” film to windows was confirmed to enhance heat-shielding performance and reduce the air conditioning power consumption required for summer cooling by 28.1%.

## [Analysis]

1. Verification by Comparison of Power Consumption

Excluding the days when the film was applied or removed, the power consumption for the period without the Air film was 325 hours 34 minutes, whereas after application of the Air film the power consumption was 249 hours 28 minutes, resulting in a reduction of 23.4%.

| | Average Outside Temp. (°C) | Average Sunshine Duration (h) | Avg. Temp. 1cm from Vent (°C) | A/C Vent Temp. (Heating) | Temp. Drop (°C) | Average Room Temp. (Under) (°C) | Average Room Temp. (Above) (°C) | Temp. Rise (°C) | A/C Operating Time (h) | A/C Power Consumption Savings (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| ① Without Air Film | **18.9** | **3.2** | **26** | **18.1** | **9.9** | **16.3** | **23.3** | **7** | **325.57** | |
| ② With Air Film | **18.2** | **2.4** | **25.7** | **18.1** | **7.6** | **18.4** | **23.5** | **5.1** | **240.47** | **23.4** |

For the temperature distribution, during the period without the Air film the average temperature at 1 cm from the window was 26.0°C, and the average air conditioner outlet temperature (on the window side) was 16.1°C, giving a difference of 9.9°C. After application of the Air film, the average air conditioner outlet temperature (on the window side) was 18.1°C, and the average temperature at 1 cm from the window was 25.7°C. With the Air film applied, the average air conditioner outlet temperature (on the window side) rose by 2.0°C, while the average temperature at 1 cm from the window decreased by 0.3°C.
Therefore, by assuming the same average air conditioner outlet temperature (window side) after application of the Air film, the temperature at 1 cm from the window without the Air film was estimated, and the effect of power consumption reduction was verified.
In addition, this air conditioning unit is designed to turn on at 25°C and off at 10°C, and does not operate at a fixed set temperature of 18.1°C. Rather, when the air conditioner operating time is shorter, the outlet temperature becomes higher.

The equation for heat transfer indoors is expressed as $q = \alpha (ti - t1) A$.
q: heat quantity (W), α: surface heat transfer coefficient ($W/m^2 \cdot K$), ti: heat source temperature (K), t1: window surface temperature (K), A: window surface area ($m^2$) Since the same room was used, the surface heat transfer coefficient α on the window side and on the corridor side is the same.
In other words, under the same outside air conditions, when the heat source temperature changes, the ratio of the temperature change between the heat source temperature and the corridor side, and between the heat source temperature and the window side, is proportional.
From the relationship 9.9 : 7.0 = X : 5.1 ⇒ X = 7.2, it follows that the difference between the average air conditioner outlet temperature (window side) and the temperature at 1 cm from the window without the Air film is 7.2°C, and the temperature at 1 cm from the window would be 26.1°C. However, the actual measured value was 25.7°C.
From this result, it was confirmed that applying the Air film has the effect of lowering the temperature at 1 cm from the window surface by 0.4°C.
In other words, taking the heat inflow through the window glass as the reference, to maintain the temperature at 1 cm from the window at 26.1°C without the Air film, it was found that the average air conditioner outlet temperature (window side) would need to be set at 18.5°C, i.e., 0.4°C higher than 18.1°C.

Next, the power consumption was calculated when the average air conditioner outlet temperature (window side) was set at 18.5℃.

| | Average Outside Temp. (°C) | Average Sunshine Duration (h) | Avg. Temp. 1cm from Vent (°C) | A/C Vent Temp. (Heating) (°C) | Temp. Diff. between A/C Vent (Ceiling) and Without Air Film (°C) | A/C Operating Time (h) | A/C Operating Time Reduction Rate (%) |
|---|---|---|---|---|---|---|---|
| ① Without Air Film | **18.9** | **3.2** | **26** | **18.1** | | **325.57** | |
| ② With Air Film | **18.2** | **2.4** | **25.7** | **18.1** | **7.6** | **240.47** | **23.4** |
| ③ Corrected | **18.2** | **2.4** | **26.1** | **18.5** | **7.2** | **234.25** | **28.1** |

The reduction when the average air conditioner outlet temperature (window side) increased from 18.1°C to 18.5°C is calculated as: 2.0 : 2.4 = 76.1 : X ⇒ X = 91.32 (reduction) ⇒ 325.57 – 91.32 = 234.25 h (power consumption).
(91.32 / 325.57) × 100 = 28.1% reduction.
In this measurement, the outside air temperature during the period with the Air film was 0.3°C higher than during the period without the Air film, but the average sunlight duration was 0.8 hours shorter. Therefore, the analysis was conducted assuming the outside air conditions were the same.

# Experiment Details and Results

## 1. Measurement Location

Hoshino Resorts Bandaisan Onsen Hotel – Restaurant, 6838-68 Sarashina Shimizudaira, Bandai Town, Yama District, Fukushima Prefecture

Window orientation: South, 13.8 m²
Windowglass: FL transparent glass Floor
Floor area: 76 m²

## 2. Measurement Dates

Without film: 1st period: July 29, 2024 – August 11, 2024; 2nd period: August 26, 2024 – September 8, 2024 (measurement time: all day)

With film: 1st period: August 12, 2024 – August 25, 2024; 2nd period: September 9, 2024 – September 22, 2024 (measurement time: all day)

## 3. Measurement Instruments

### 3-1 Thermocouple Automatic Recording Thermometer

**Thermocouple:** K-type, 0.1 mm **Logger:** HIOKI Temperature Logger LR5051, 2 channels

**Measurement Locations**

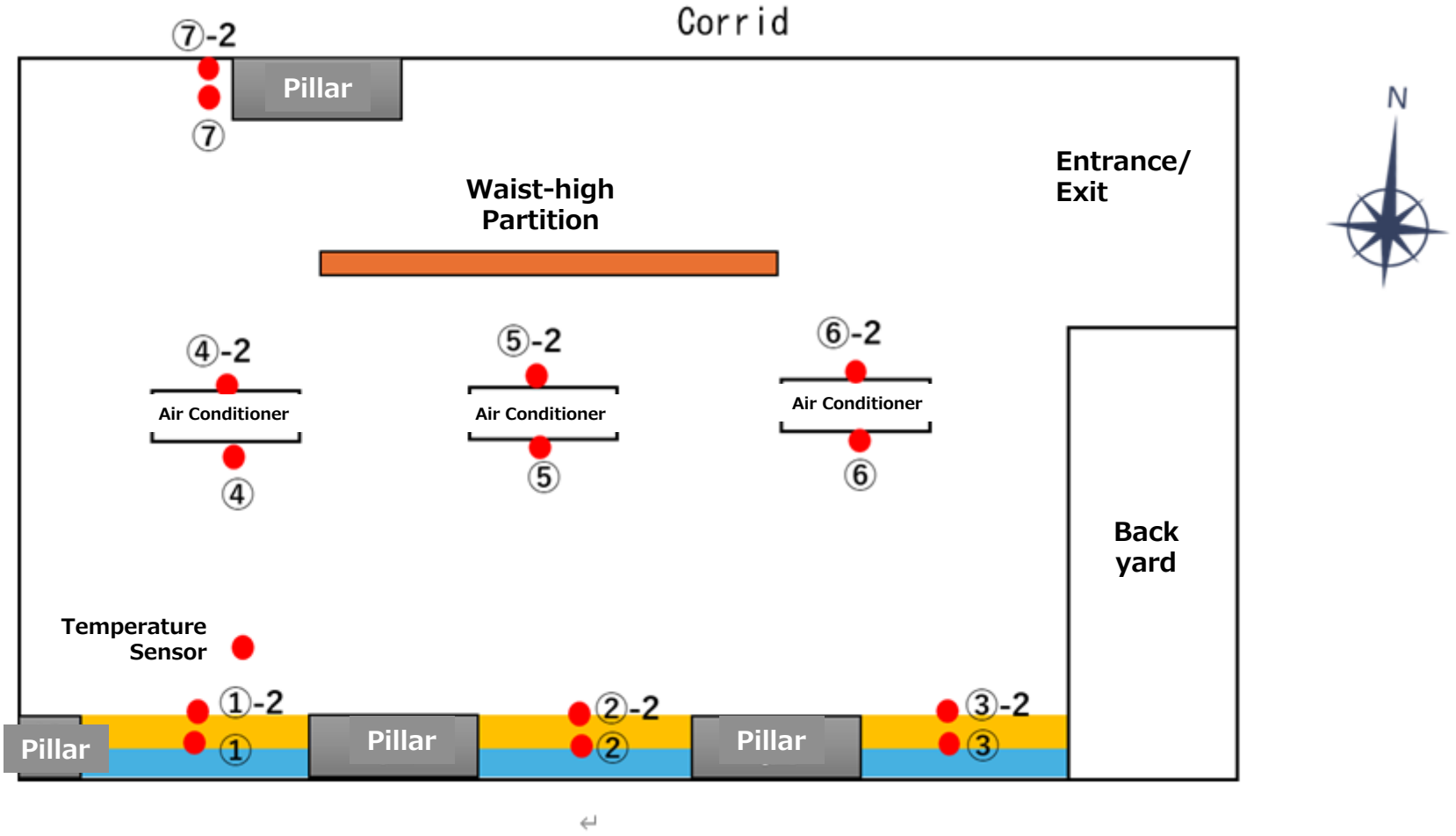
3 locations at 1 cm from the window surface 2 locations for temperature at the wall side 3 locations at 5 cm from the window surface
3 locations for A/C vent temperature (window side) 3 locations for A/C vent temperature (hallway side)

### 3-2 Measurement Conditions

a. Indoor: normal usage
b. Air conditioner settings: normal settings
c. Outside air conditions: adopted from observation records of **Washikura area**, Tokyo District Fukushima Meteorological Observatory

# Overall View of the Building

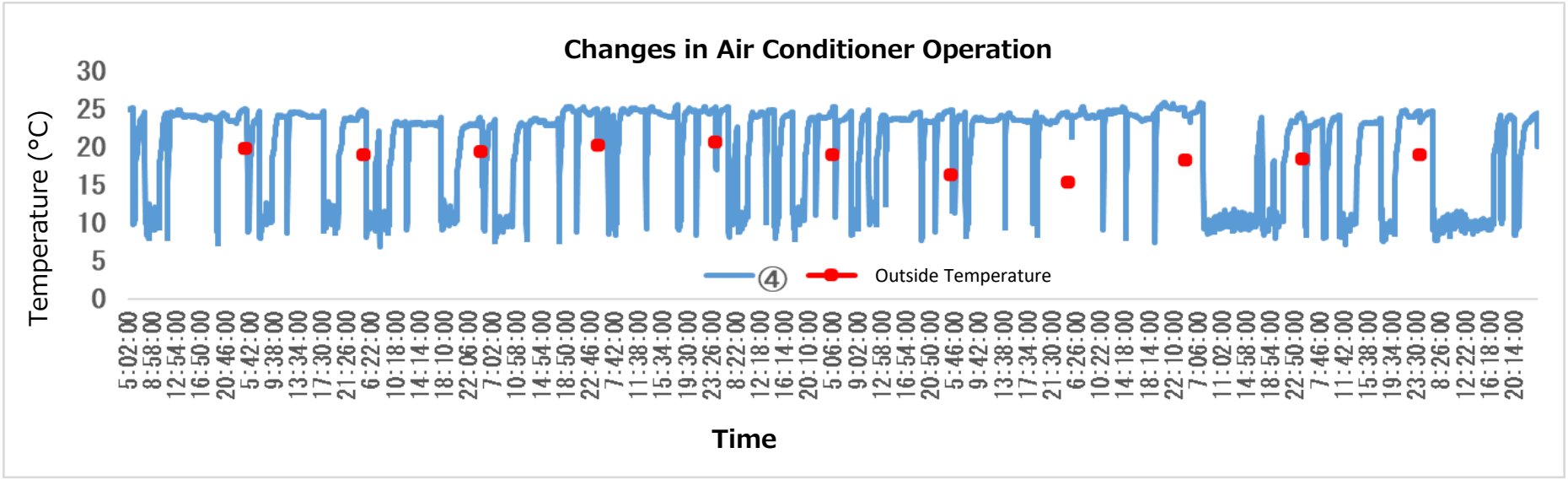
# Layout

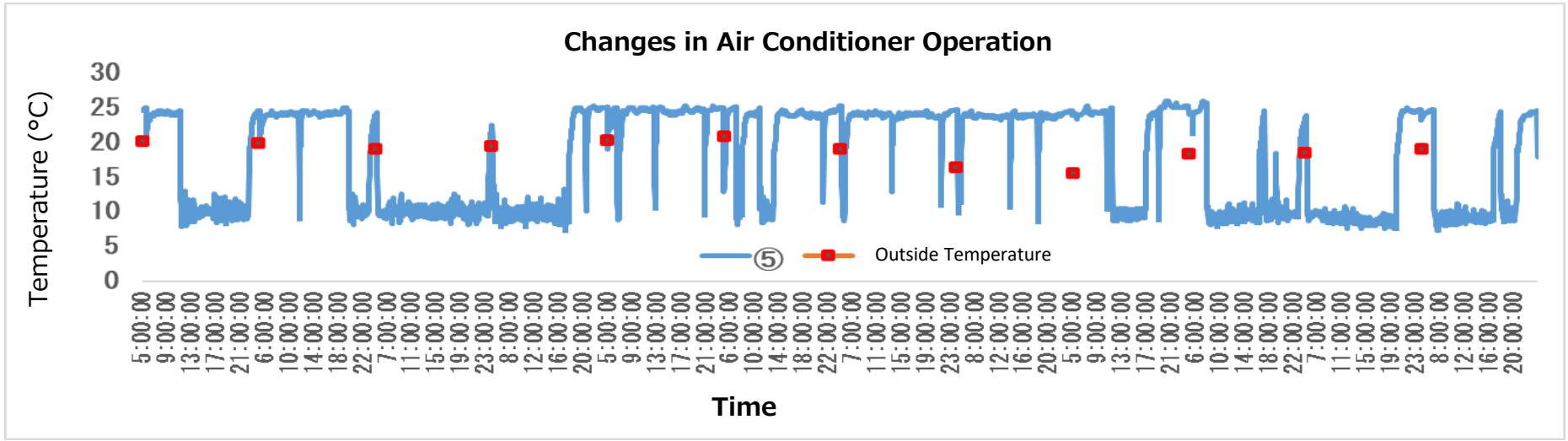


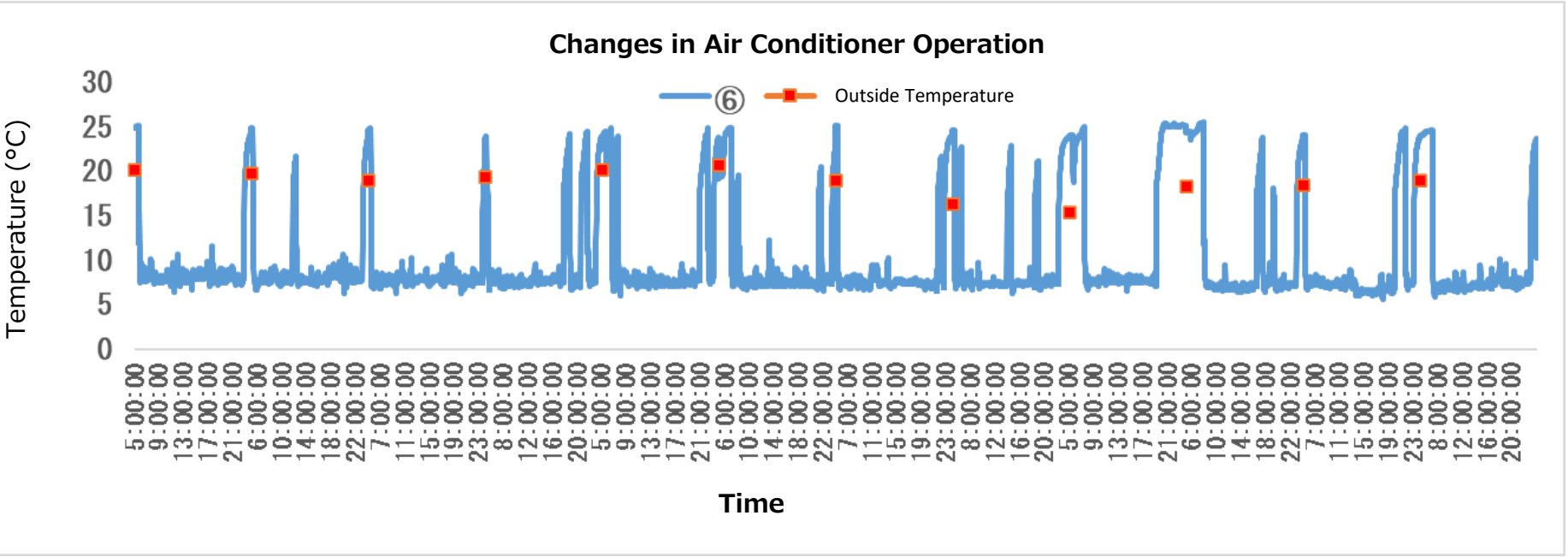

Temperature at 1 cm and 5 cm from the window surface (2 points each): glass side Air conditioner outlet (2 points each)
Temperature near walls (2 points)

# Data

## Without Air Film



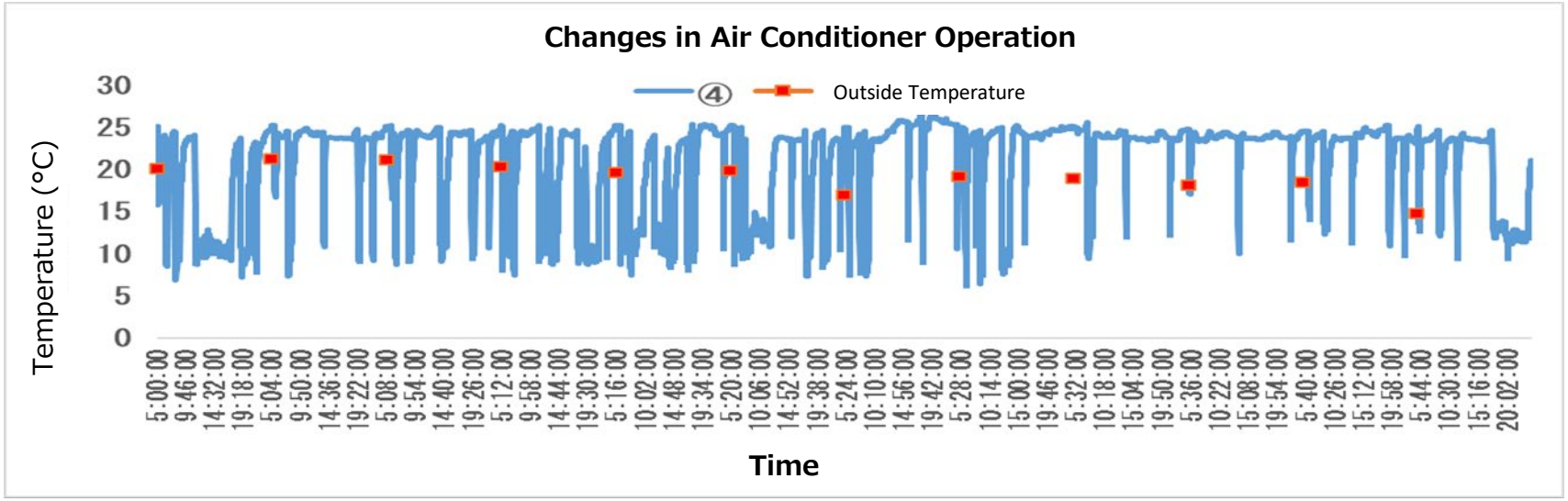


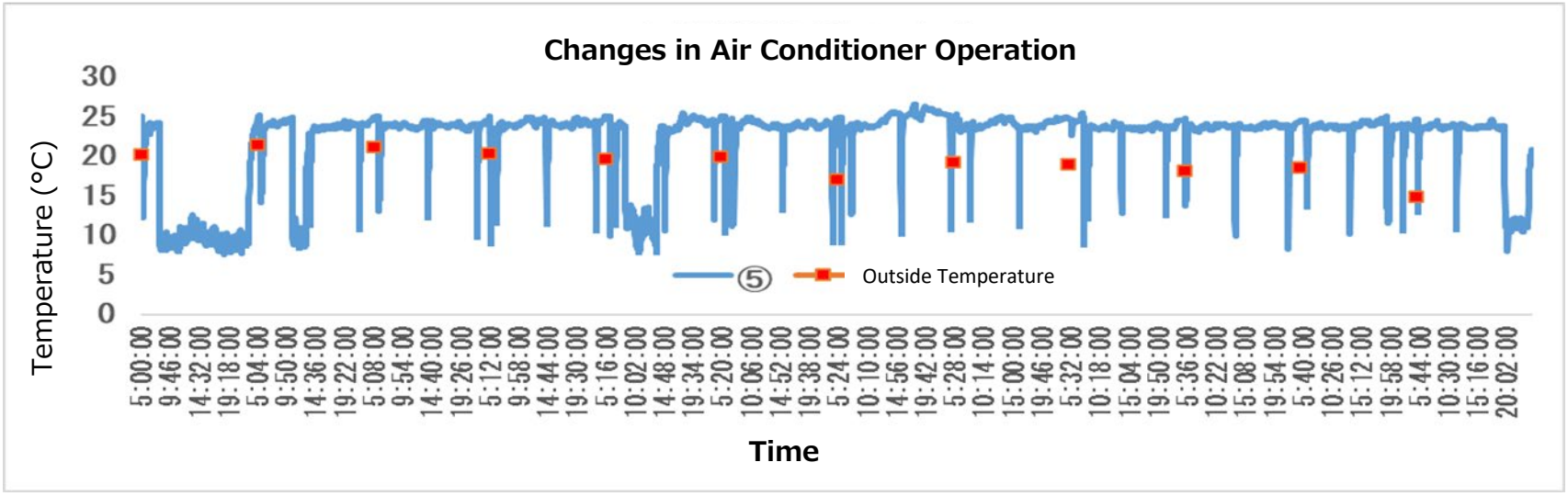

| | Measurement Point ④ | Measurement Point ⑤ | Measurement Point ⑥ | Total |
|---|---|---|---|---|
| **A/C Operating Time (h) Without** | **52.80** | **95.19** | **177.27** | **325.57** |

Of the three air conditioners, air conditioner (6) was operating at full capacity, while (4) and (5) were operating at 1/3 to 1/2 capacity.

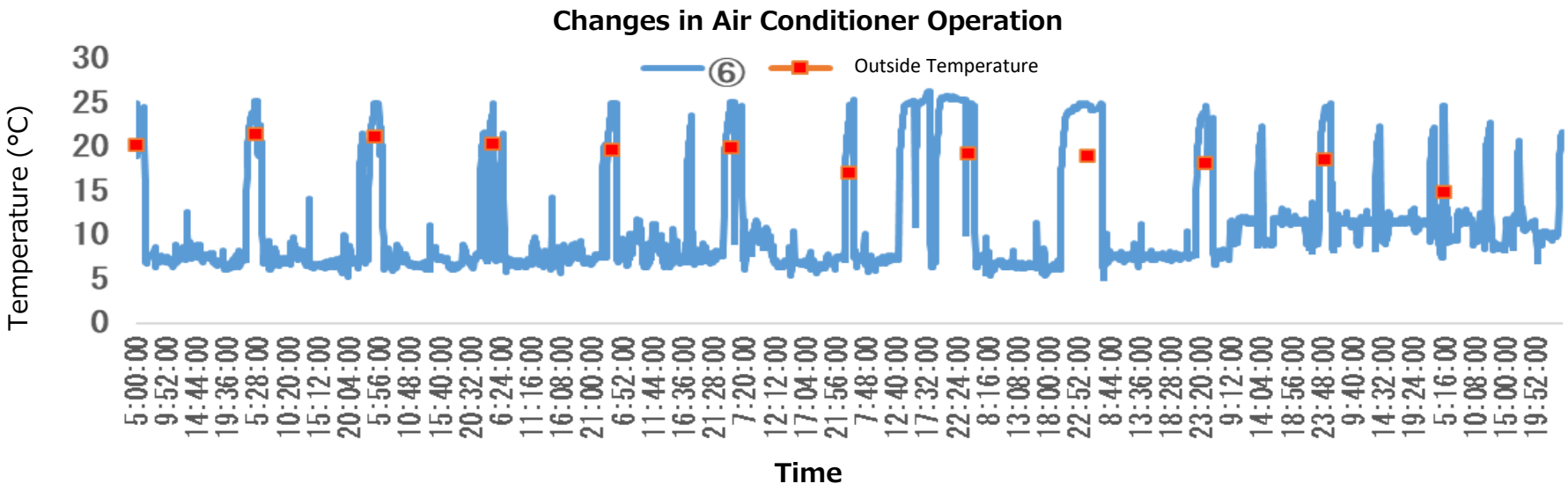
# Data

## With Air Film



# Data

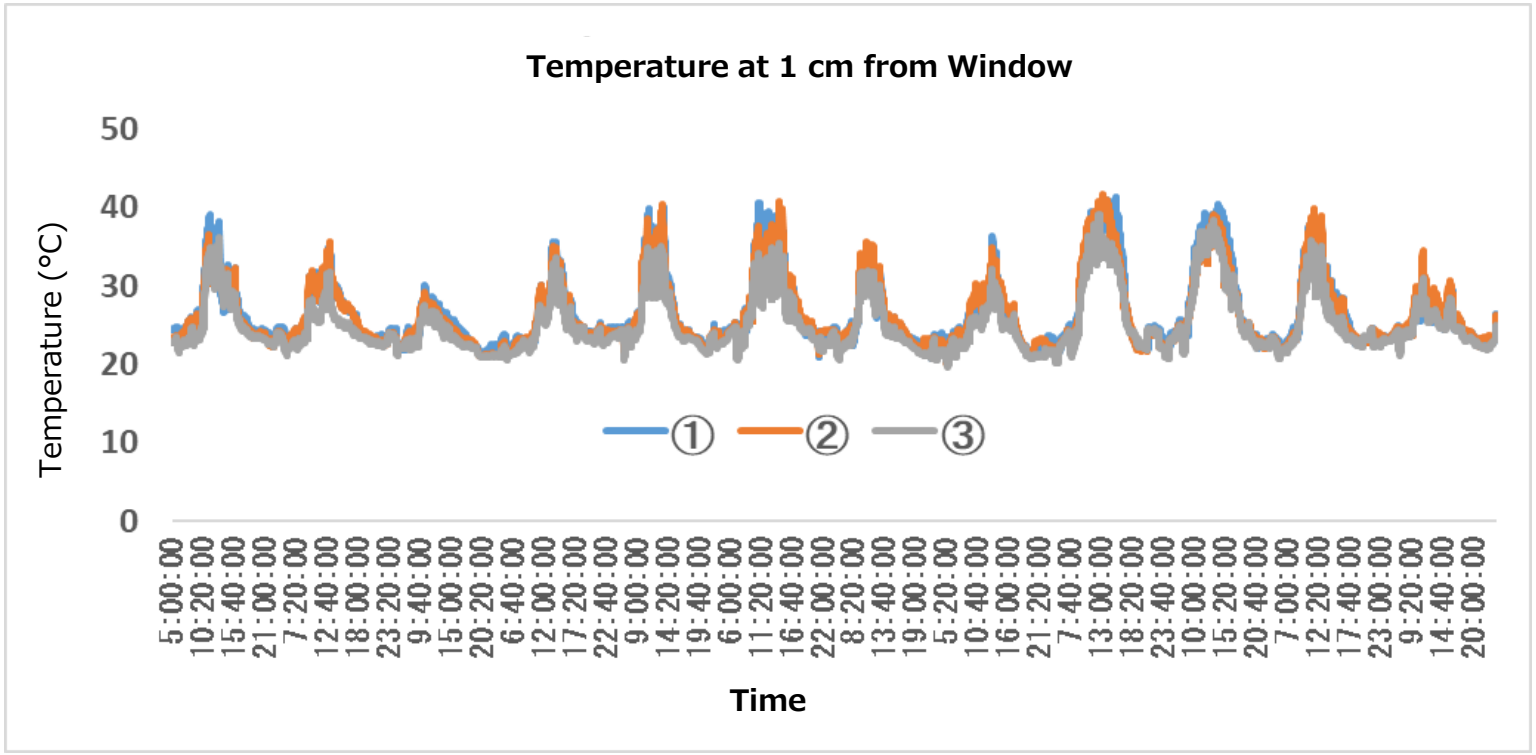



| | Measurement Point ④ | Measurement Point ⑤ | Measurement Point ⑥ | Total |
|---|---|---|---|---|
| **A/C Operating Time (h) With** | **33.21** | **27.93** | **188.33** | **249.47** |

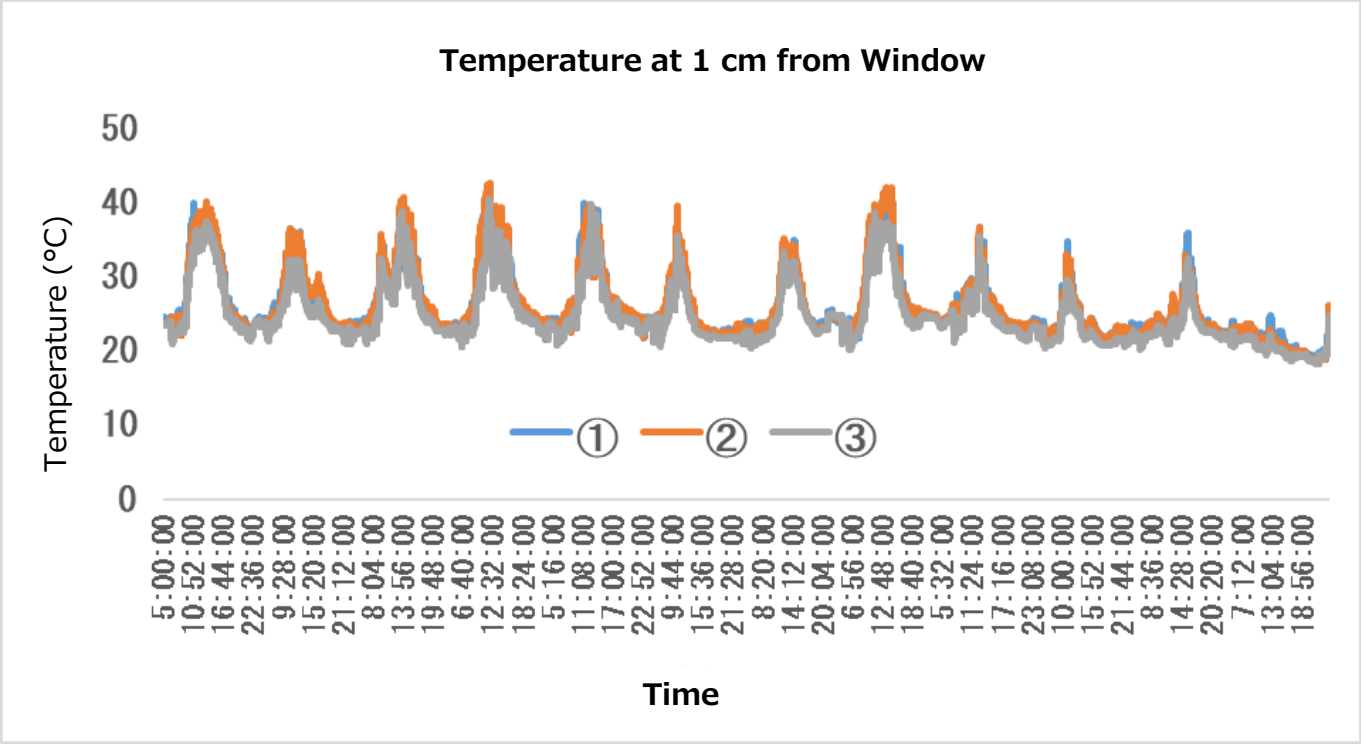
Of the three air conditioners, air conditioner (6) was operating at full capacity, while (4) and (5) were operating at about 1/5 capacity. It can be seen that applying the Air film to the windows reduces air conditioner operation and lowers the cooling load.

## Original data

### 1)　1) Without Air Film – Temperature 1 cm from the Window

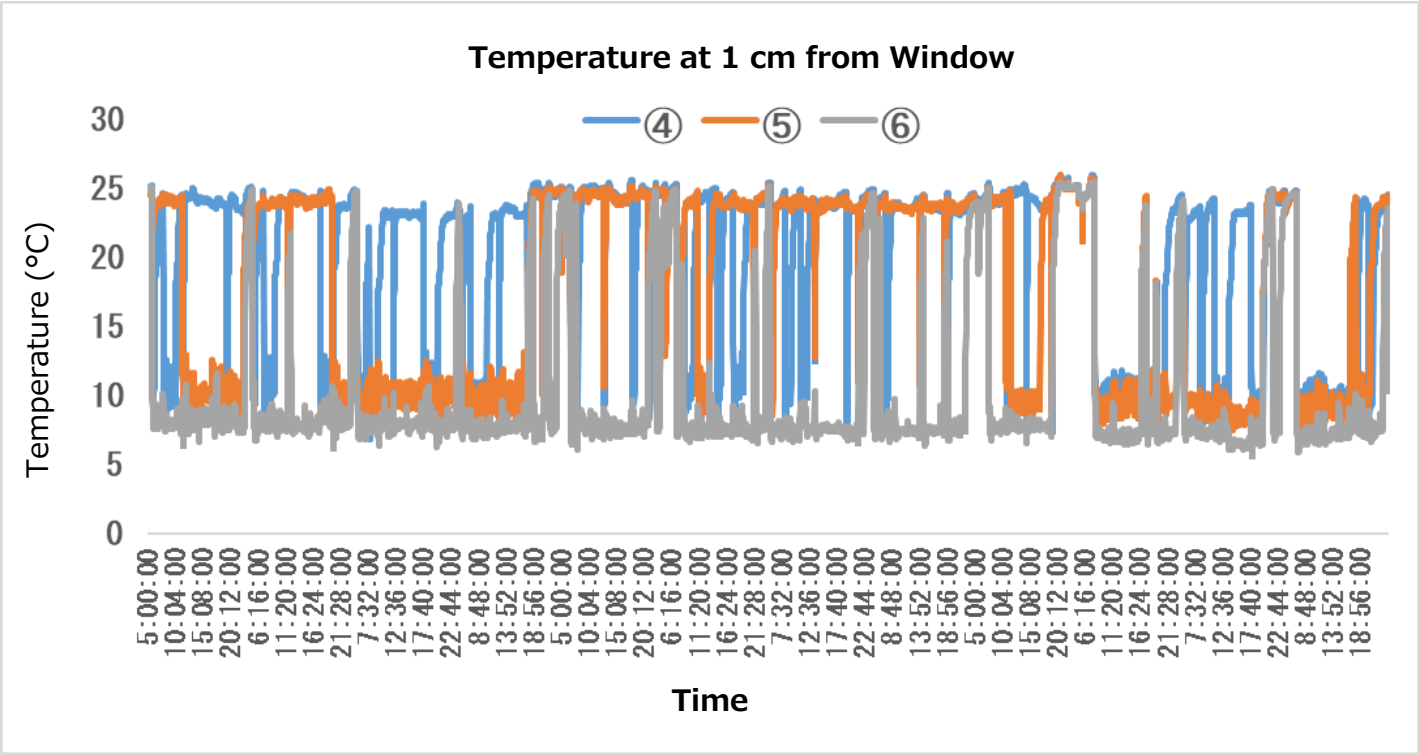


## 2) With Air Film – Temperature 1 cm from the Window



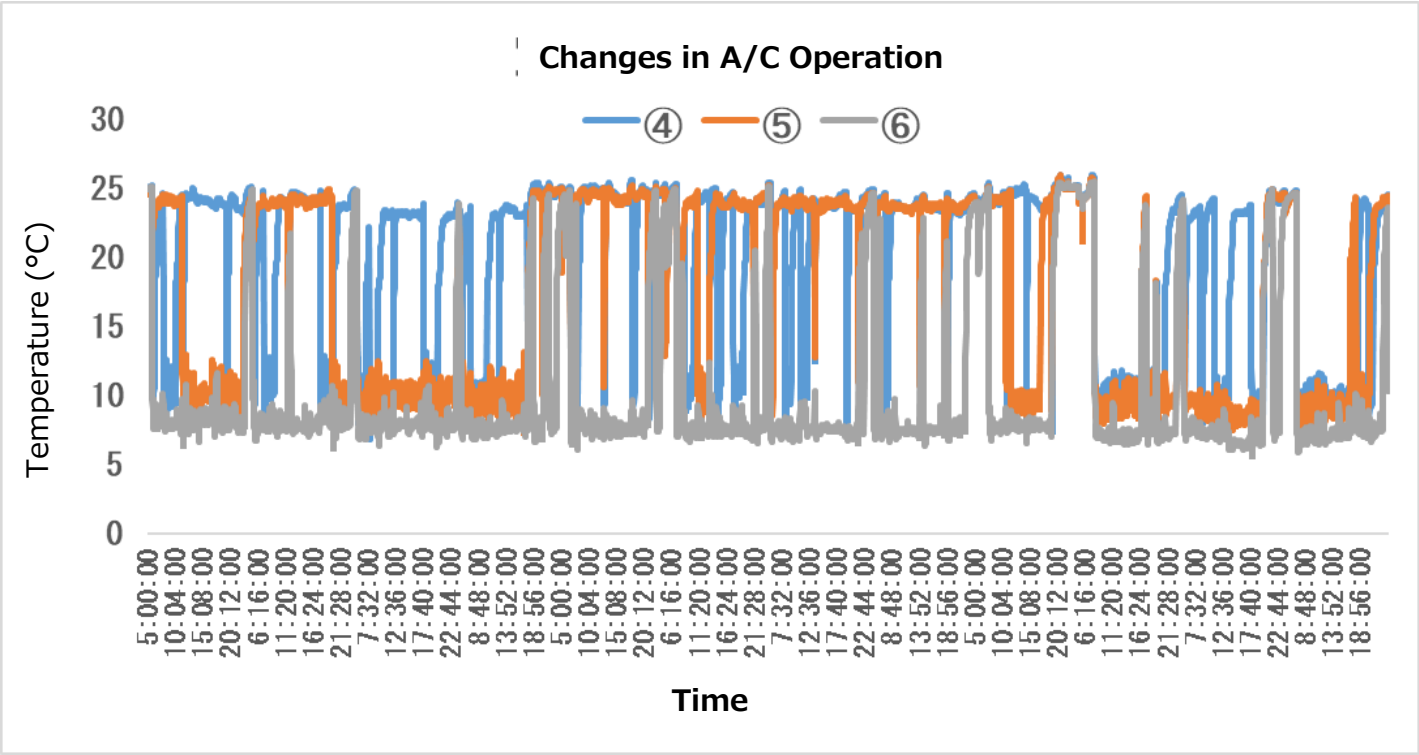

The average temperature at 1 cm from the window was 25.7°C, 0.3°C lower than without the Air film.

## 3) Without Air Film – Air Conditioner Outlet Temperature (Window Side)



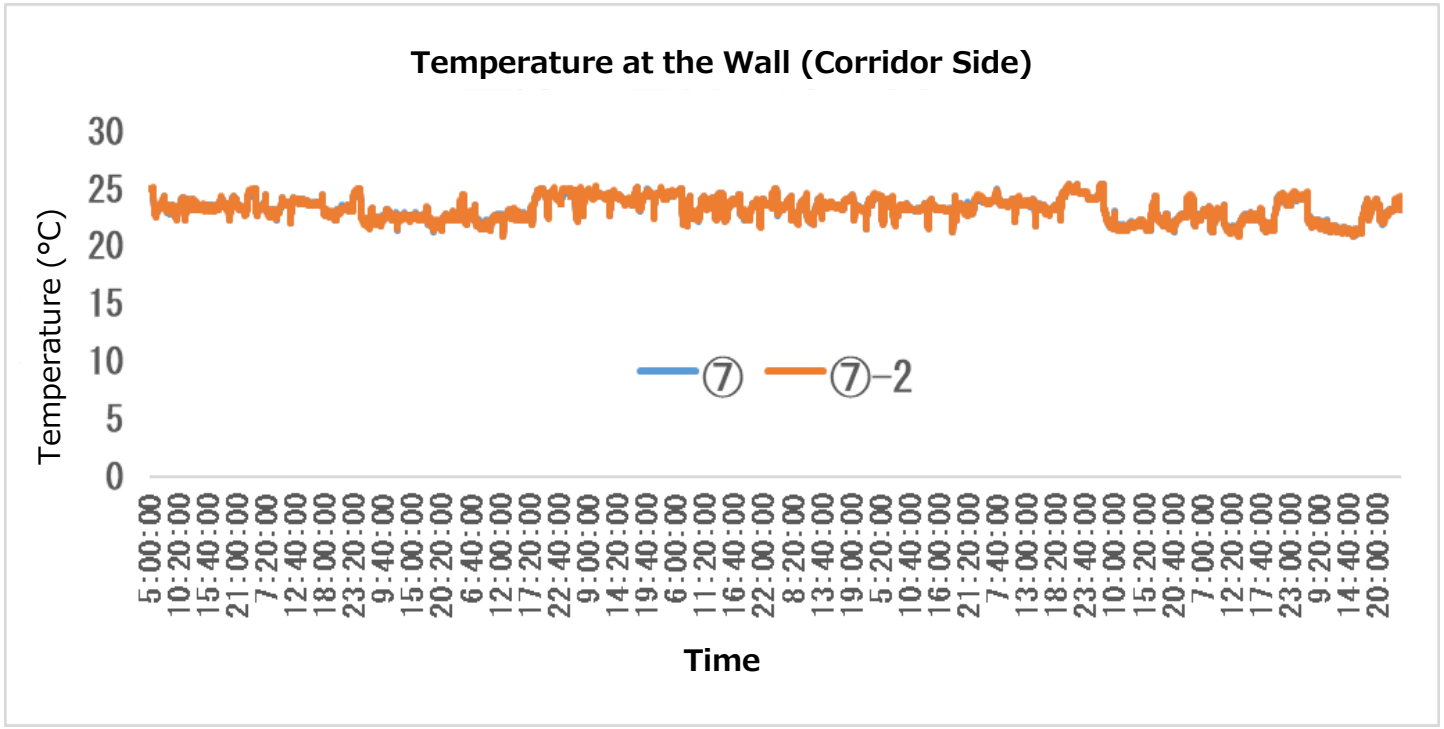

From the figure, it can be seen that the three air conditioners were operating separately.
The average outlet temperature was 16.1°C, the temperature at 1 cm from the window was 26.0°C, giving a difference of 9.9°C.

## 4) With Air Film – Air Conditioner Outlet Temperature (Window Side)



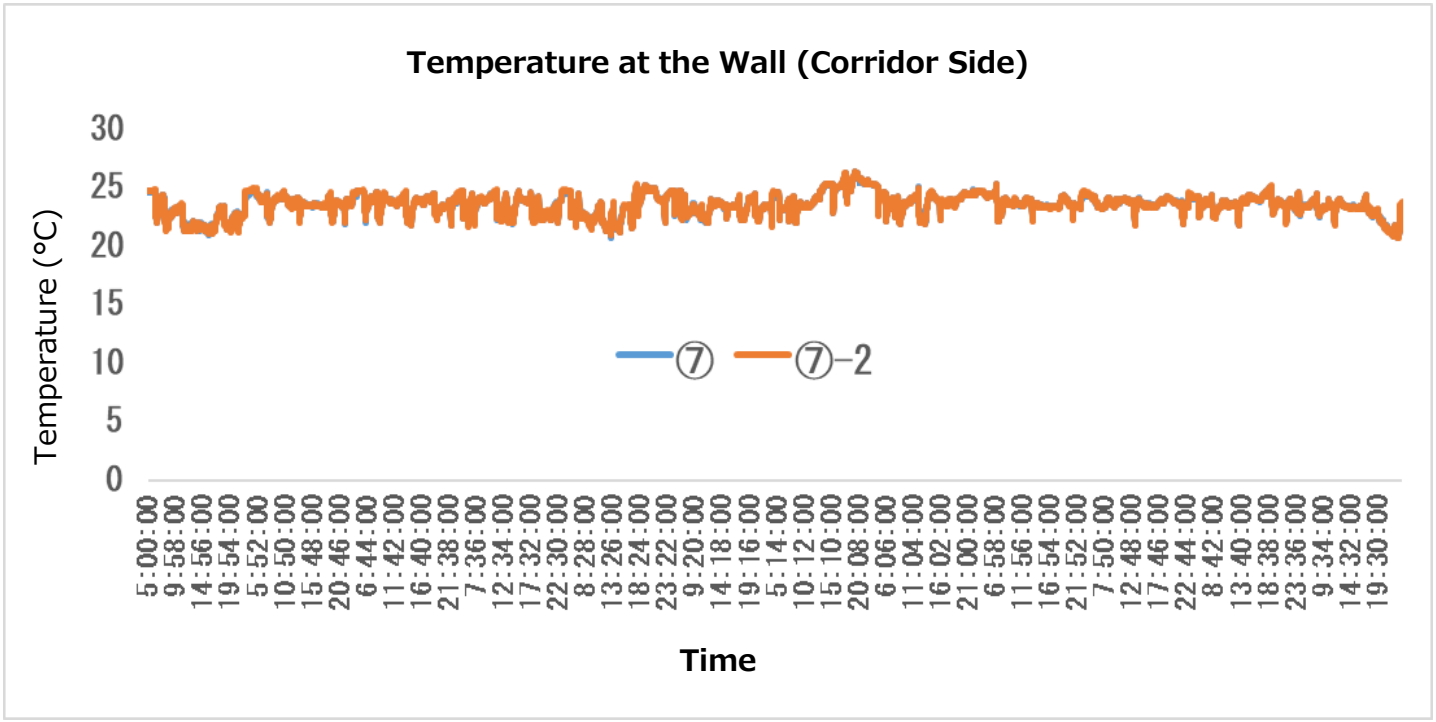

From the figure, it can be seen that the three air conditioners were operating separately.
The stop time was longer than without the Air film, and the average temperature was 18.1°C, 2.0°C higher.
The temperature difference from 1 cm from the window was 7.6°C, 2.3°C smaller than without the Air film.

## 5) Without Air Film – Corridor Side Temperature



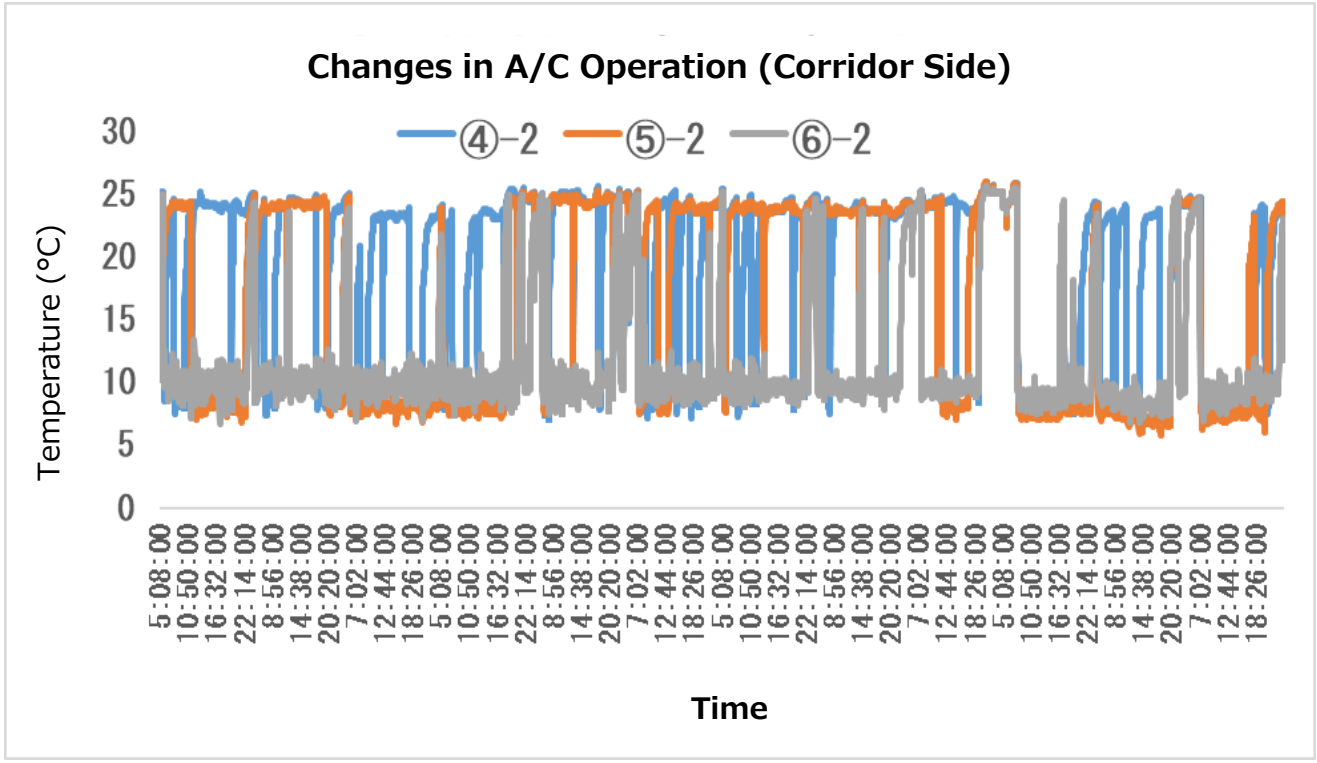

The average temperature was 23.3°C.

## 6) Without Air Film – Corridor Side Temperature



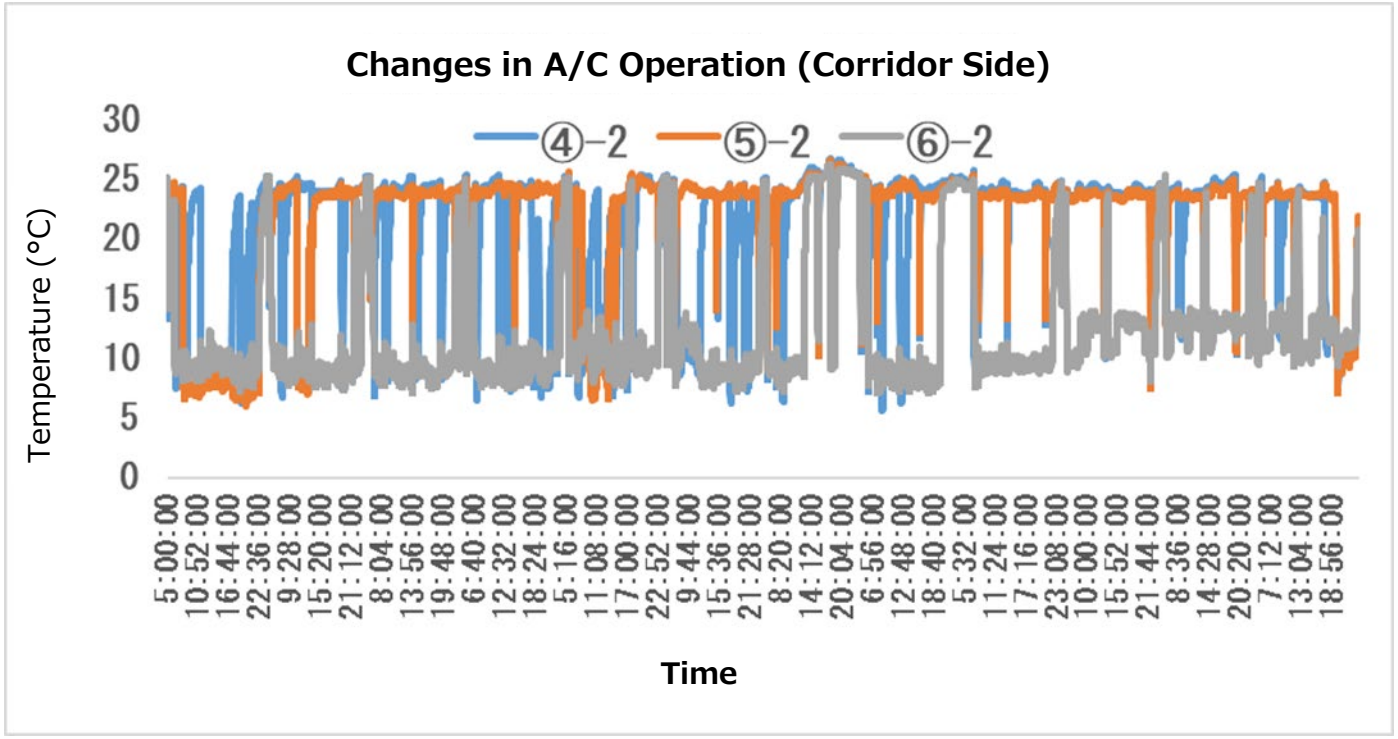

The average temperature was 23.5°C, 0.2°C higher than without the Air film (23.3°C).

## 7) Without Air Film – Air Conditioner Outlet Temperature (Corridor Side)




From the figure, it can be seen that the three air conditioners were operating separately.
The average temperature was 16.3°C, giving a difference of 7.0°C from the corridor side temperature.

## 8) With Air Film – Air Conditioner Outlet Temperature (Corridor Side)




From the figure, it can be seen that the three air conditioners were operating separately.
The stop time was longer than without the Air film, and the average temperature was 18.4°C, 2.1°C higher.
The difference from the corridor side temperature was 5.1°C, 2.9°C smaller than without the Air film.