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Establishment of a method to control temperature distribution in a cylindroconical tank

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Abstract

At Asahi, we focus on controlling fermentation temperatures corresponding with yeast growth phases that affect beer flavor. We reported at the 2015 ASBC Annual Meeting that unpleasant flavors in beer could be reduced by controlling the fermentation temperature using mathematical-based methods (T. Irie, 2015). In this study, we developed a method to control temperature distribution in cylindroconical tanks. Fermentation temperatures inside of tanks are typically monitored with a single thermometer. However, temperature distribution was found to be non-uniform when measured at multiple locations in the tank and also differed between tanks. Here, we aimed to equalize temperature distribution within cylindroconical fermentation tanks at the set temperature value to improve beer quality. We needed to establish a method to predict temperature distribution without measurement. It shows the process of establishing the indicator of temperature distribution in cylindroconical tanks as below.

Purpose

- In this study, we aim to establish a method to control temperature distribution in order to ensure the quality of beer by minimizing differences in temperature distribution among tanks.

Non-uniformity of temperature distribution

We first measured the temperature distribution in a cylindroconical tank using 4 thermometers at various positions (Fig. 1, left). The measurements revealed that the lower portion of the tank was cooler than the set temperature, particularly during the first few days of fermentation.

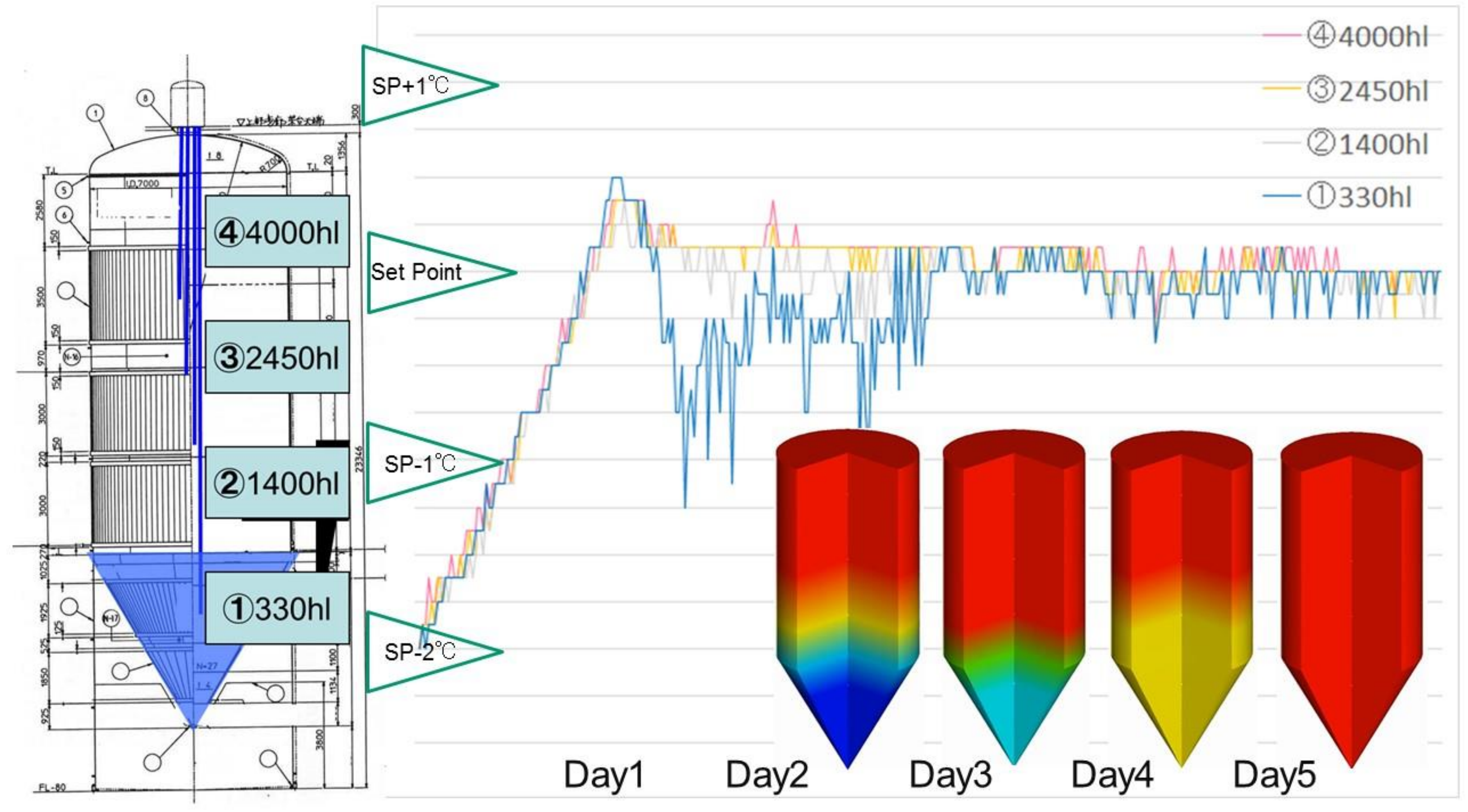


Fig.1 Temperature distribution in cylindroconical tank

Hypothesis: excess heat of cooling causes overcooling

We hypothesized that variations in heat of cooling among tanks influenced on temperature distribution. We focused on cooling time to know the degree of cooling in tanks (Fig. 2).

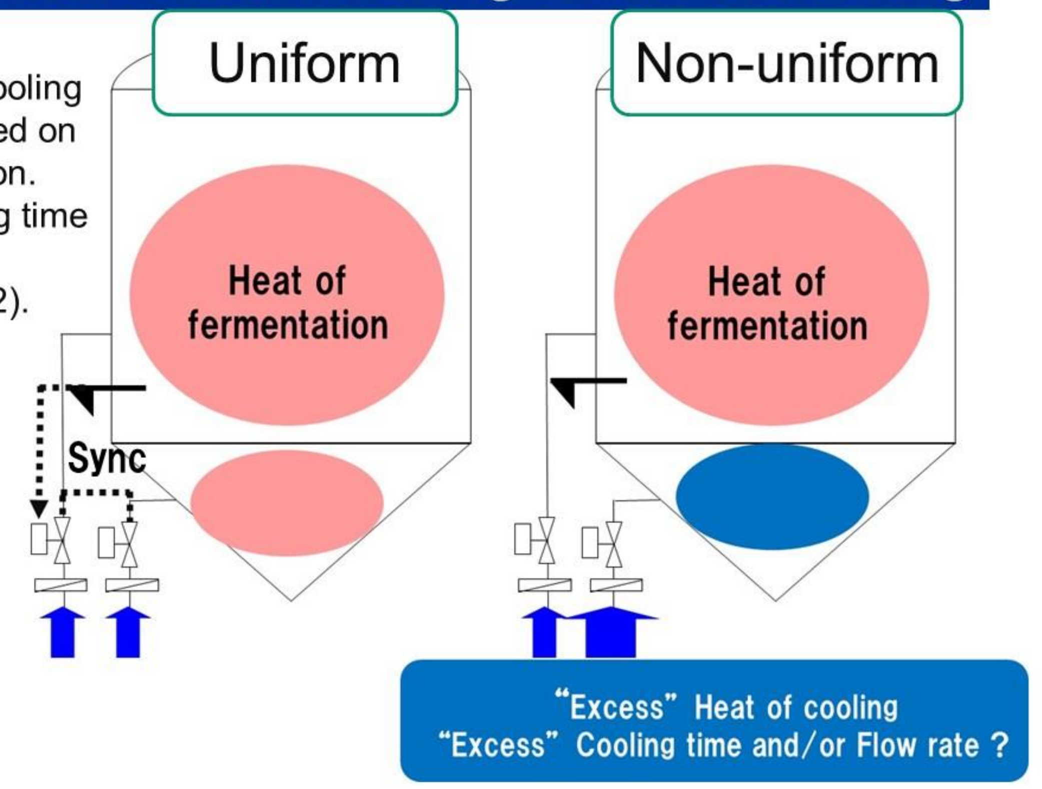


Fig.2 Hypothesis: relationships between heat of cooling and temp. distribution

Differences in cooling time between tanks

Result: Cooling time in non-uniform tanks was shorter and longer than that in uniform tanks

We investigated the relationship between cooling time and temperature distribution in 14 tanks (Fig. 3). Cooling time was found to be closely related with temperature distribution.

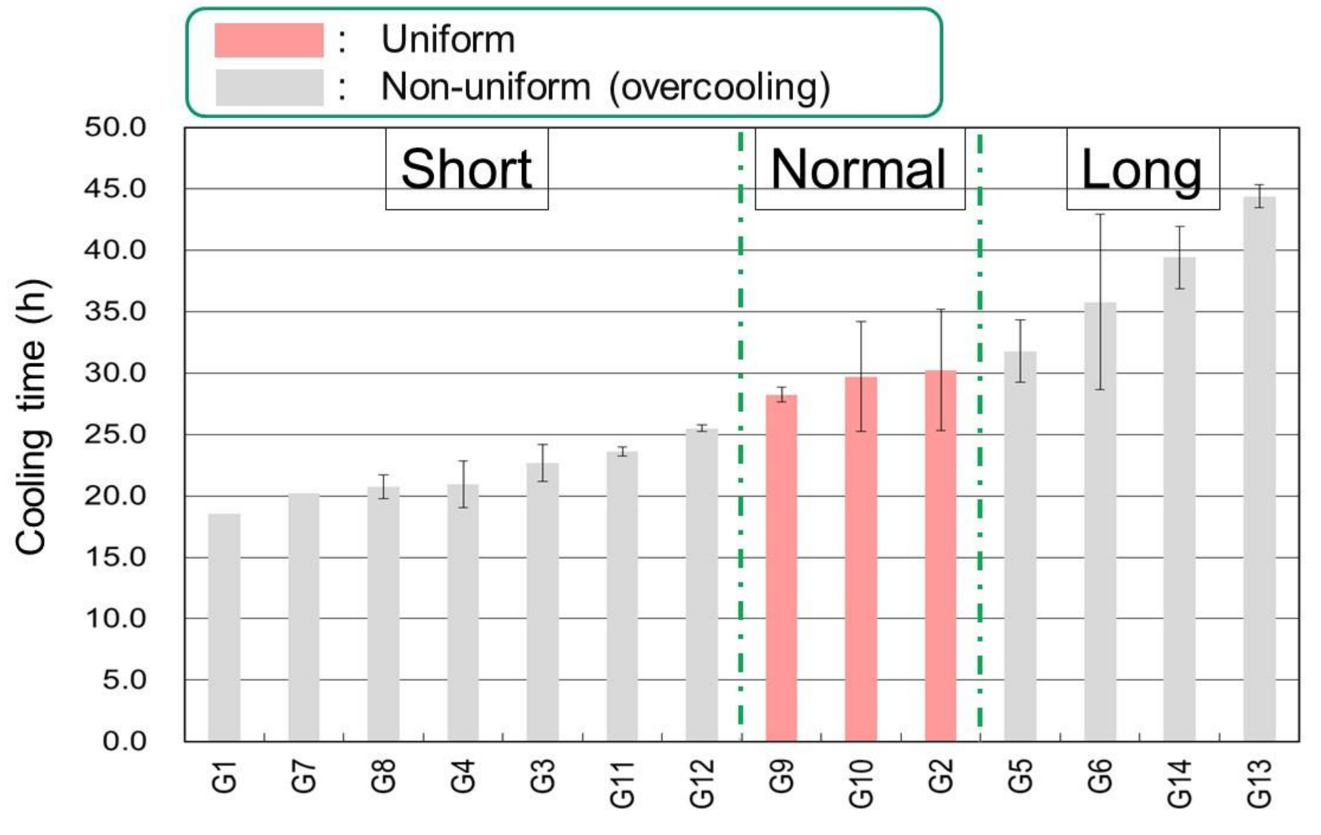
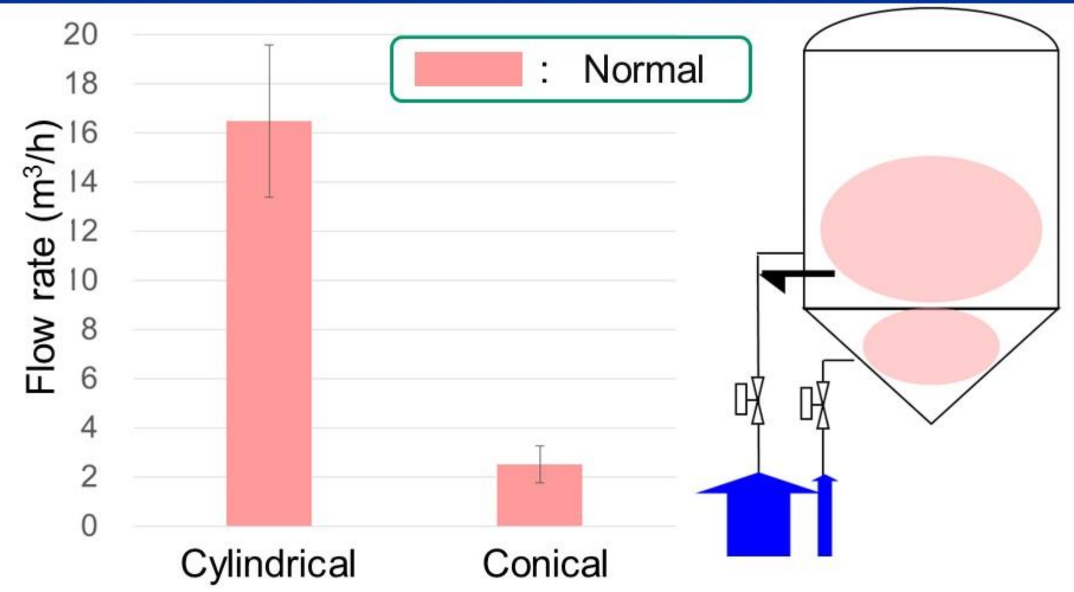


Fig.3 Variation in cooling time in individual tanks

To classify the patterns of cooling and temperature distribution, coolant flow rate was measured (Fig. 4). If the ratio of coolant flow rate between cylindrical and conical regions was not well balanced, overcooling occurred (Fig.4, Short and Long). Maintaining the appropriate ratio of flow rate is critical for uniformity of temperature distribution.

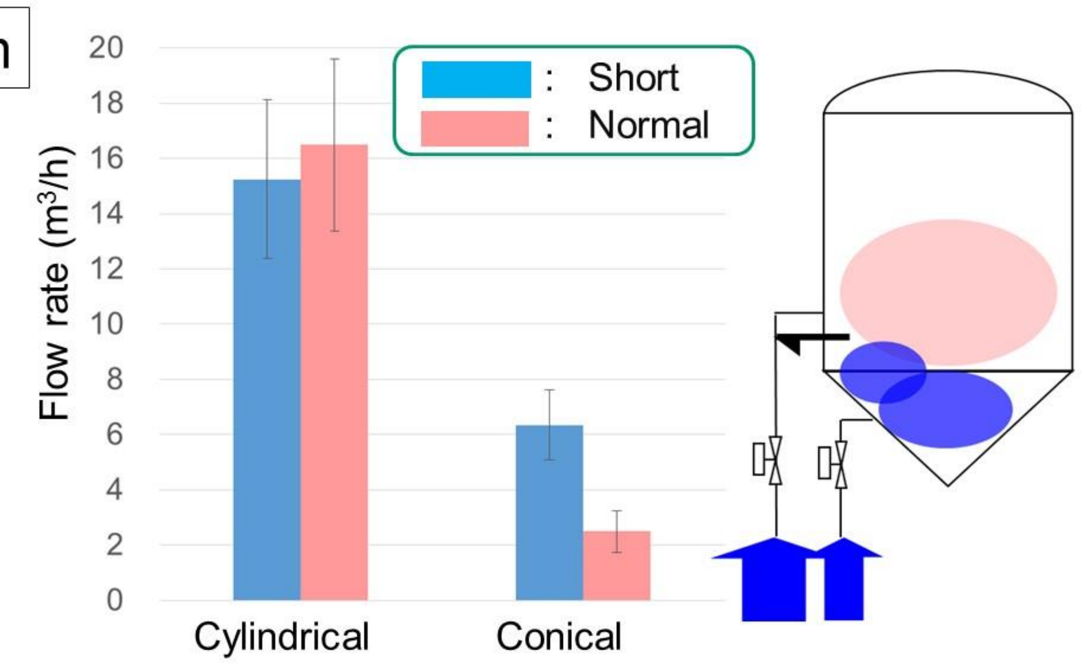
Relationships between cooling time and temperature distribution

Normal : Uniform



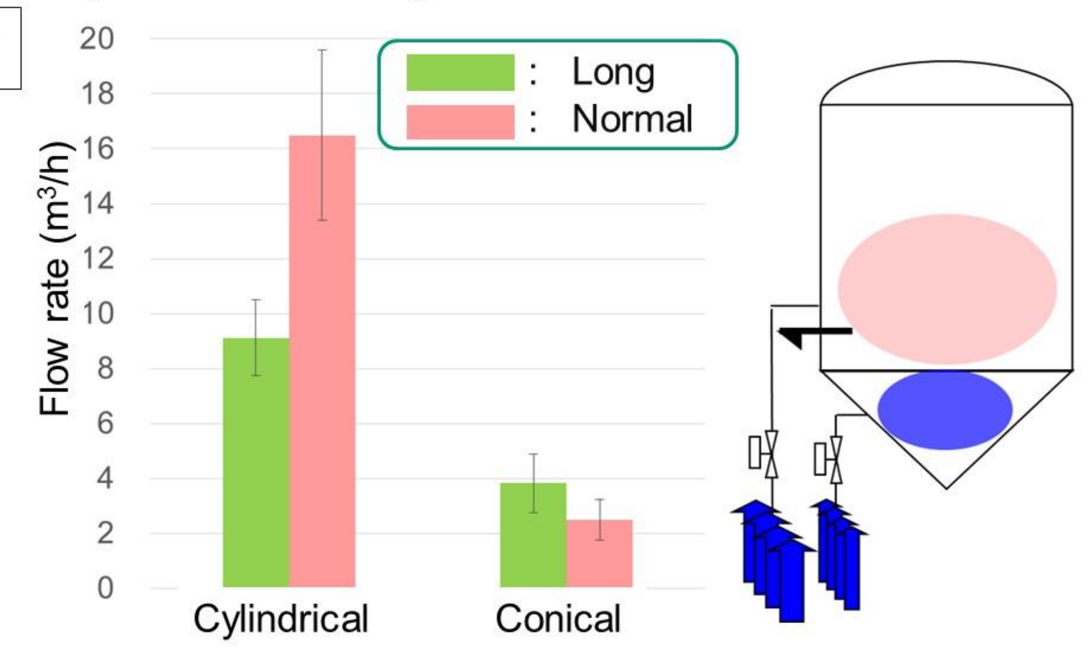
・Appropriate ratio of coolant flow rate between cylindrical and conical regions

Short : Non-uniform



・Excess coolant flow rate in conical region
・Cooling time was short by excess cooling heat around a thermometer

Long : Non-uniform



・Cooling time was long because flow rate was insufficient in cylindrical region
・Overcooling occurred by excess cooling heat in conical region resulting from synchronism with cylindrical region

Fig.4 Relationships between coolant flow rate and temperature distribution

Indicator of temperature distribution

Indicator: Ratio of flow rate between cylindrical and conical regions

Two-dimensional mapping of the flow rate in cylindrical and conical regions was used to control temperature distribution (Fig. 5). The temperature distribution changed from that shown in Fig. 5 to that in Fig. 6 by altering the coolant flow rate. Using this approach, uniformity of the temperature distribution was achieved, and the heat of cooling was practically controlled (Fig. 7).

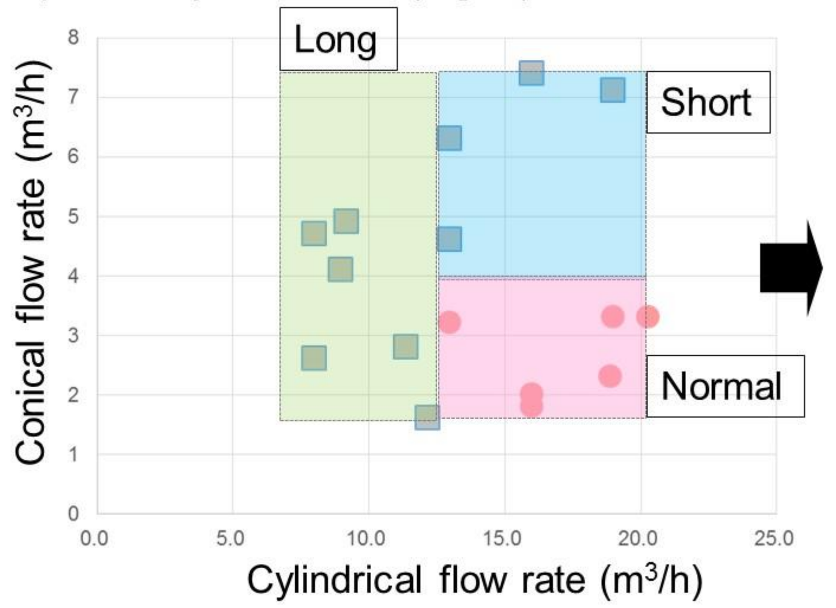


Fig.5 Indicator of temperature distribution (before coolant valve adjustment)

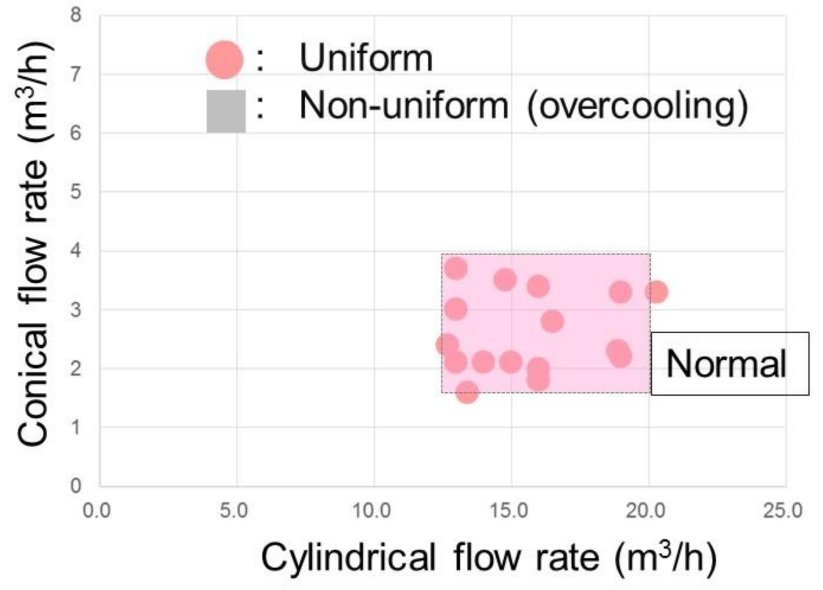


Fig.6 Indicator of temperature distribution (after coolant valve adjustment)

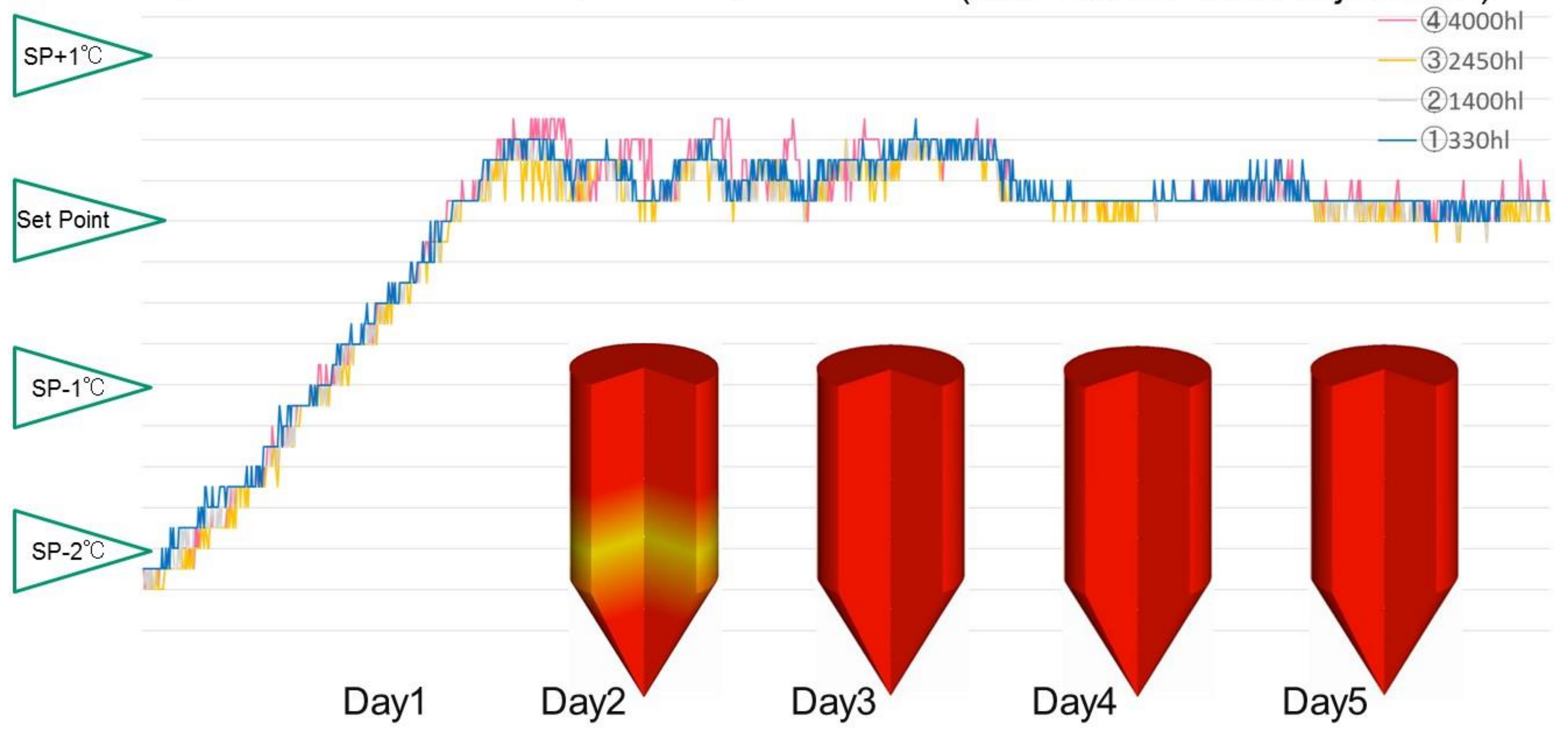


Fig.7 Temperature distribution in a cylindroconical tank

Conclusions

- A method to control temperature distribution in cylindroconical tanks was established.
- The ratio of flow rate between cylindrical and conical regions can be utilized as an indicator of temperature distribution.
- Appropriate flow rate and cooling time were determined based on practical measured data.
- Future work: evaluation of beer flavor under coolant flow rate regulated conditions.

References

1. Taku Irie ; O-36, Annual Meeting 2015, American Society of Brewing Chemists
2. Kunze 3rd Edition Technology brewing and malting, Chapter4, pp490, 2004