STUDY ON OPTIMUM PID CONTROLLER SETTINGS FOR TEMPERATURE CONTROL IN A GROWTH CABINET

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To obtain the criteria for the optimum setting of the PID controller of temperature, the effect of the setting combinations of proportional band (P_B), reset time (T_I) and rate time (T_D) on the response characteristics in temperature control was analyzed by measuring the control area and the settling time in step response of air temperature in a growth cabinet (KG 208). From the results, following points were made clear:

- 1) The response characteristics were remarkably affected by P_B setting; the P_B was most responsible for the control area and the settling time.
- 2) When P_B was more than 50%, the control area and the settling time were very large, and in most cases, the temperatures were not settled during an hour.
- 3) When P_B was 3%, the cycling occurred in all cases, regardless of T_I and T_D settings.
- 4) When P_B was 10%, the control area and the settling time were very small. However, when T_D was 2 min, the cycling occurred even when P_B was 10%.
- 5) Optimum setting was given when P_B is 10%, $T_I=10\sim 20$ min and $T_D=0\sim 0.5$ min.

It is known that PID control action is very effective for high accurate control of temperature in a growth cabinet.¹⁾ However, the effect of the settings of proportional band (P_B), reset time (T_I) and rate time (T_D) in the PID controller on the response characteristics in temperature control in the growth cabinet has not been analyzed, and it is practically complicated to get optimum setting²⁾ of PID controller of temperature.

Present paper deals with the analyses of the relation between the combinations of the P_B , T_I and T_D settings and response characteristics in temperature control, to obtain the criteria of the optimum setting of the PID controller for the temperature control in a growth cabinet.

MATERIALS AND METHODS

Temperature control system. In the growth cabinet (KG 208) used in this study, the refrigerators were continuously operated; constant cooling capacity of 2,500 kcal was used. The PID action was adapted for feedback control of temperature; the feedback signal was led into the PID controller (Type EGC, Y.E.W. Co.)³⁾ and the capacity of the electric heater was regulated by PID control action.¹⁾ The maximum heating capacity was 12,900 kcal.

Temperature detection. At the central part in the growth compartment, the air temperature was detected by a micro-thermister (Hypodermic Probe, Y.S.I.

Co.) and recorded by electric recorder. By this system, the air temperature was detected with accuracy of $\pm 0.3^\circ\text{C}$ and with time constant of 0.6 sec.

Test Procedure. At various setting combinations of P_B , T_I and T_D in the PID controller, step responses (10°C to 20°C , 20°C to 30°C and 30°C to 40°C) were analyzed by measuring the settling time and the control area, and relationships between settings of P_B , T_I and T_D and response characteristics in temperature control were examined.

RESULTS AND DISCUSSION

Figure 1 shows the step responses of the temperature, when P_B is 100%, T_I is 20 min and T_D is 2 min. In this case, the response speed was very slow and a peak brought about during the rising period, and thereafter the overshoot was found. The temperature was not settled during an hour. Accordingly, both of the settling time and the control area were very large. From this response characteristics, it could be estimated that the setting combination in this case is not available for temperature control.

Figure 2 shows the step responses of the temperature, when P_B , T_I and T_D

Fig. 1 Step responses of temperature when P_B is 100%, T_I is 20 min, and T_D is 2 min.

Fig. 2 Step responses of temperature when P_B is 10%, T_I is 1 min, and T_D is 2 min.

Fig. 3 Step responses of temperature when P_B is 3%, T_I is 20 min, and T_D is 2 min.

Fig. 4 Step responses of temperature when P_B is 10%, T_I is 10 min, and T_D is 0.05 min.

are 10%, 1 min and 2 min, respectively. At the desired value of 20°C, both of the settling time and the control area were small, and good response characteristics were obtained. At the desired values of 30°C and 40°C, however, the cycling occurred, and the temperatures were not settled. This fact demonstrates that in some cases, the setting combinations of P_B , T_I and T_D should be changed according to the variation of the desired values in program control.

Figure 3 shows the step responses of the temperature, when P_B , T_I and T_D are 3%, 20 min and 2 min, respectively. In this case, the typical cycling occurred at all the desired values of 20, 30 and 40°C. Accordingly, the temperatures were not settled, and the control area was large.

Figure 4 shows the step responses of temperature, when P_B , T_I and T_D are 10%, 10 min and 0.05 min, respectively. At all of the desired values, the settling time and the control area were very small, and good response characteristics were obtained. Accordingly, it could be estimated that this setting combination of P_B , T_I and T_D is an example of the typical optimum setting.

Figure 5 shows the control area and the settling time in step responses of temperature at various setting combinations of P_B , T_I and T_D . The P_B was most

Fig. 5 Control area and settling time in different setting combinations of P_B , T_I and T_D in PID controller of temperature.

responsible for the control area and the settling time. When P_B was 10%, most of the control areas and settling times were small. However, when T_I was less than 5 min, settling time became somewhat larger. When P_B was 10%, and T_D was 2 min, the cycling occurred regardless of T_I setting. When the P_B was 3%, the cycling occurred. When P_B was more than 50%, the temperature was not settled in most cases.

From these results, it is clear that the settings of P_B , T_I and T_D remarkably affect the response characteristics in temperature control in the growth cabinet, and the optimum setting can be given when $P_B=10\%$, $T_I=10\sim 20$ min and $T_D=0\sim 0.5$ min.

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<和文抄録>

グロースキャビネットの温度制御における PID 調節器の最適調整に関する研究

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PID 制御動作が空気温度制御に著しく有効であることはすでに認められているが、PID 調節器における比例帯 (P_B)、積分時間 (T_I) および微分時間 (T_D) の設定条件と、温度制御の特性との関係が明らかでないために完全な最適調整が困難な場面がある。本研究では PID 調節器の最適調整の資料を得るためにグロースキャビネットにおける PID 調節器の比例帯、積分時間および微分時間を種々の条件に設定し、空気温度のステップ応答特性について制御面積および整定時間を測定して解析した。

- 1) 空気温度のステップ応答における制御面積と整定時間は比例帯設定条件に最も著しく支配された。
- 2) 比例帯を 50% 以上に設定した場合、制御面積および整定時間、ともに著しく大となり、ほとんどの場合 1 時間以内に整定しなかった。
- 3) 比例帯を 3% に設定した場合、積分時間、微分時間の設定条件に関係なく、サイクリングを生じた。
- 4) 比例帯を 10% に設定した場合、制御面積および整定時間、ともに小となったが、微分時間が 2 分の場合にはサイクリングを生じた。
- 5) 最適調整の条件は比例帯 10%、積分時間 10~20 分、微分時間 0~0.5 分であった。