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Improvement of the Negative Pressure Control System in the Reactor Hall

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1.0 Introduction

Internal air of the reactor hall is discharged to the outside through a filter, and the internal pressure is maintained as the negative pressure, 2.5 mmWG more than atmospheric pressure. [1] In this situation, when the outside atmospheric pressure changes drastically, a problem occurred for the set negative pressure could not be automatically maintained; when the system is broke down, another problem rose as it is very difficult to secure an expensive PID Controller.

A new measuring system was applied by selecting an auto-tuning controller to improve a stability of negative pressure control. As a result, stability and response character against a drastic change of atmospheric pressure has improved, increasing the operational efficiency of the negative pressure control system.

2.0 Principle of Negative Pressure Measurement

In order to maintain the negative pressure in the reactor hall, 4 fans are installed in a double, and normally only 2 fans are running. An inverter connected to each fan controls the revolution of the fan and in turn controls the negative pressure as well.[2] The measured negative pressure signal is entered to the controller, and the output signal of the controller, which is calculated to control the negative pressure, controls the revolution of the inverter. The principle is the Feedback control method that calculates the output so as to eliminate the pre-set value and deviation by measuring the negative pressure of the reactor hall. This measure is a control algorithm that produces an output by adjusting the results of proportional, derivative and integral control actions, and it is shown in Figure 1

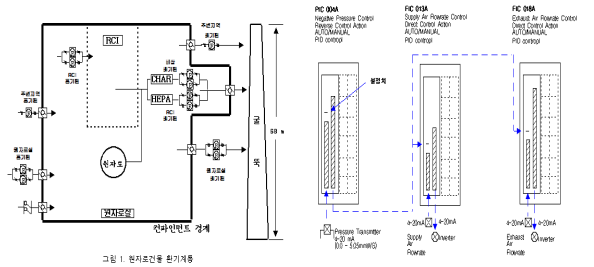

Figure 1. Conceptual Diagram of the Negative Pressure Control System

Proportional control (P) calculates the output so that feedback is proportional to the input of a control section to the pre-set value and there is no deviation with the pre-set values. Derivative control action (D) adds and subtracts the manipulated value in proportion to the speed of change of an error with the pre-set value and prevents the error from increasing. Integral control action (I) controls the pre-set values by integrating the area which multiplies the size of error and the time of error and it is a controlling method not to have a residual error. This is shown in Figure 2.

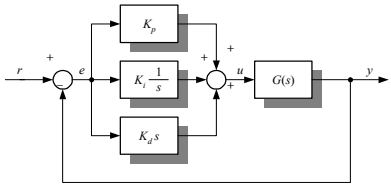

Figure 2. Feedback Control System of PID Controller

Transfer function is $C(s) = \frac{U(s)}{E(s)} = K_p + K_d s + \frac{K_i}{s}$, and here Kp, Kd, and Ki are proportional coefficient, derivative coefficient, and integral coefficient, respectively.

3.0 Composition and Characteristics of Measuring System

The measuring equipments used to control the negative pressure include 2 sets of differential pressure transmitters and 6 sets of PID controllers. Differential pressure transmitter is a D/P form of transducer which measures the atmospheric pressure and relative pressure in the range of 0-12.7 mmWG to produce 4-20mA current signal. PID controller acknowledges this signal as feedback signal, and after control operation with the pre-set value of 2.5mWG, it transmits 4-20mA current signal again to an inverter.

One of the most important points in negative pressure control is that the setting of each optimum number should be optimized so that the pre-set value is more stable and response is faster. For this condition, in the initial operation of the reactor hall, a test is performed regarding a negative pressure in the optimal the reactor hall. The initial value is set to be 4mmWG and the optimal values of control optimum numbers were selected, as shown in Figure 3.

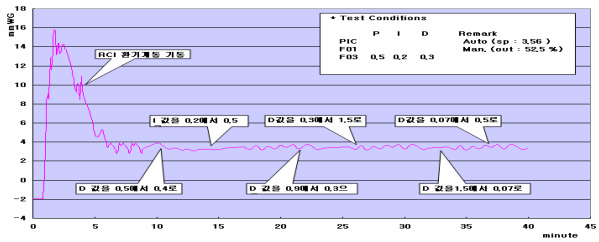

Figure 3. Selection of Control Variables for PID Controller

A problem is: when the ventilating fan is first run, a response time is about 5 to 7 minutes for the pressure to increase up to 16mmWG and reach the pre-set value. Since the area of the reactor hall is in a large volume of 39000m^3, considering the fact that it cannot sensitively react to the change of injected air volume, the response time is not a long time. However, due to the fans in a different system, which continue to run, the response time increased up to more than 10 minutes. Another problem is that: when RCI ventilation system is operated or stopped while a normal control is sustained, or when a strong wind blows at sensory port of differential pressure transducer, intermittent Hunting Phenomenon occurs. This is described in Figure 4.

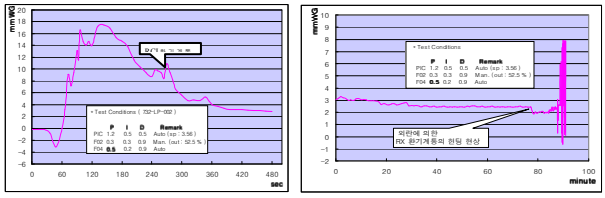

Figure 4. Response Time of Negative Pressure in the Reactor Hall and Hunting Phenomenon

Its cause is that a positive number for the time to find the pre-set value of pressure is set inappropriately to make the system unstable. However, when it is too stabilized, it is possible to have control deviation for the inserted disturbance, causing a long recovery time. The latter case is also taken into consideration.

4.0 Characteristics of the Improved System

A theoretical purpose of optimal control is to satisfy three elements − no residual deviation, stability, and fast response. In order to meet these conditions, a signal distributor and auto-tuning controller with excellent stability in negative pressure control and fast response were selected. The selected controller is Yamatake SDC31 with such functions as Multi- Input, Auto Tuning, and Communication (RS485/232) as well as precision of ±0.1%FS.[3] Signal distributor for the distribution of negative pressure signal uses the transformer insulation method which makes four outputs with one input and has linearity of 0.02%FS. Its external shape and signal characteristics are shown in Figure 5.

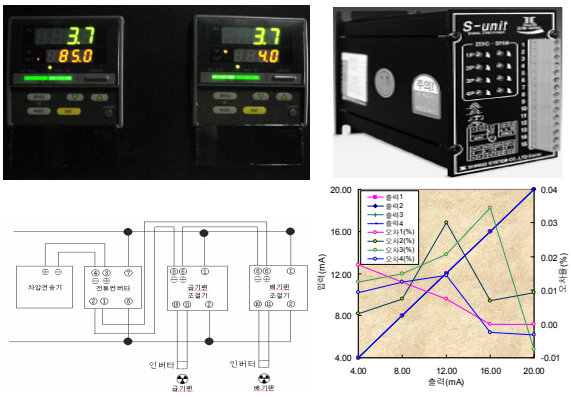

Figure 5. External Form and Character Curves

After removing the controller previous used, a controller and signal distributor for replacement were installed. As a result of the one-month field test, it was found that response time and stability against disturbance have considerably improved. The results of measurement while ventilation system in the reactor hall is normal operated for three times are shown in Figure 6. The response time was reduced from about 10 minutes to 2 to 3 minutes. Maximum amplitude decreased from 18mmWG to 9mmWG, while the change of amplitude from the operation of RCI ventilation system also decreased from 3mmWG to 0.5mmWG, indicating that the reduction ratio of amplitude had a considerable improvement. In the case of Hunting phenomenon that used to occur due to disturbance in the process of measure negative pressure in differential pressure transducer, not once did it occur hitherto for five months.

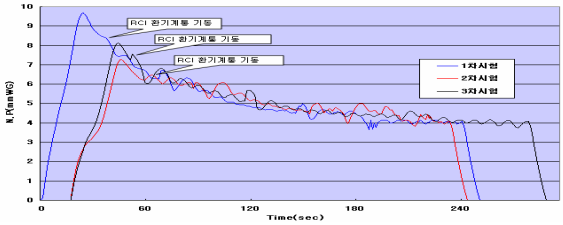

Figure 6. Maximum Amplitude and Deviation

5.0 Conclusion

In order to solve the problems with the negative pressure control system in the reactor hall, a new system was constructed by using a signal distributor and negative pressure controller with a function of Auto-Tuning. The three-month test with the new system demonstrated the following improvements:

* The response time of a controller for the pre-set value of negative pressure decreased from approximately 10 minutes to 2 to 3 minutes.
* The maximum amplitude of negative pressure at the initial operation of ventilation system was reduced from 18mmWG to 9mmW, and the change of amplitude resulted from the operation of RCI ventilation system was also reduced from 3mmWG to 0.5mmWG.
* Hunting phenomenon that occurred in the process of measuring the negative pressure because of disturbance did not occur at all hitherto for five months after the new system was installed.
* It became easy to secure a spare of the previous negative pressure controller which was expensive.

REFERENCES

[1] “Safety Analysis Report”, KAERI/TR-710/96, KAERI, 1996.
[2] Kopec, “Design Manual of Reflector Building HVAC system,” KM - 732 - DM - P001 Rev.1
[2] Operating Instructions for Model SDC31 Series Digital Indicating Control, Yamatake Corporation.