EXPERIMENT NO: 5

NAME OF EXPERIMENT: PROCESS CONTROL

AIM OF THE EXPERIMENT

Liquid Level Control

Understanding how to control the level of liquid in a container and how to calculate control parameters.

Flow Rate Control

Understanding how to control the flow rate of a fluid flowing in the pipe and how to calculate the control parameters.

Pressure Control

Understanding how to control the pressure in a closed container and how to calculate the control parameters.

Temperature Control

Understanding how to control the temperature in a closed container and how to calculate the control parameters.

THEORETICAL FUNDAMENTALS

In general terms, control is to direct behavior towards a purpose in living things or inanimate physical systems. In nature, we come across control events that occur almost everywhere and at all times, according to some natural laws. We name this type of control "natural control." Examples of natural control include keeping human body temperature constant through blood pressure and sweating and keeping the sugar concentration in human blood constant through a hormone.

There is another form of control that is carried out with the help of a person himself or with a series of devices he creates with his mental effort, which is called artificial control.

It is common to believe that since automatic control and automation are used in the same sense among the public, the main reason for using automatic controllers is to minimize the workforce requirement in factories. After correcting this misdiagnosis as "saving people from heavy and boring jobs," we must add that the real reasons reflect only a small part. The main reasons are improving product quality and controlling rapid changes that cannot be controlled by human ability. For this reason, when automatic control is applied, the production amount increases, and a uniform (certain features) product is obtained.

Today, automatic control devices are widely used in almost all technological processes. Chemical engineers, especially those working in petroleum, chemicals, iron and steel, food, power industries, are more concerned with controlling temperature, pressure, flow rate, fluid level, and similar process variables used in process industries.

A process control system consists of three main components. These are the measuring element, the controller, and the final control element. The measuring element measures the feature

desired to be controlled in the process, for example, temperature, and sends this information to the controller. The controller compares the measured value according to the user's setpoint, and the final control element can be the heater in temperature control by doing the work required to bring the error closer to zero. The control process continues until the difference between the measured value and the setpoint is zero.

In general, all control mechanisms measure the output (temperature, T in the example) of the system and act by its input (heater power in the example, q) when necessary. Thus, a closed-circuit control occurs. This concept that uses information about the deviation of the system from the desired state is called *feedback control*.

Proportional Control (P): If the control mechanism affects the severity proportional to the error's magnitude, the control system of this type is called *proportional control*. Kc denotes proportional control constant.

$$q(t) = q_s + K_c(T_R - T) \quad (1)$$

Integral control (I): When it is understood that the control problem cannot be solved with the infinite increase of proportional controller constant K_c, the control problem's solution can be investigated by adding an integral controller. In addition to the proportional control (T_R-T) acting on the heater at the error rate, this new control system operates more effectively in an integral control by the same error acting on the heater at the integral rate.

$$q(t) = q_s + K_c(T_R - T) + K_R \int_0^t (T_R - T)dt \quad (2)$$

Derivative Control (D): The rate of change of the process error is calculated by calculating the slope of the error over time and the derivative gain product of this rate of change.

$$q(t) = q_s + K_c(T_R - T) + K_d \frac{d(T_R - T)}{dt} \quad (3)$$

The term derivative slows down the rate of change of the controller output. The derivative control integral reduces the overshoot intensity caused by the component and increases the combined controller-process stability. However, the signal's derivation increases the noise in the signal, and thus this term in the controller is susceptible to noise in error. If noise and derivative gain are significant, it causes instability in the process.

EXPERIMENTAL SETUP AND METHOD

Figure 1. Experimental setup

Turn on the computer and upload the test file you are going to do. Turn on the DC power supply that supplies the control unit. Turn on the control unit.

Liquid Level Control Experiment

- Enter the desired setpoint on the computer.
- To reach the setpoint, let the pump water from the tank below and pump water to the tank above.
- Determine the most appropriate controller parameters combination required by the Ziegler-Nichols method to change the controller parameters with a computer's help to reach the desired set point.

Flow Rate Control Experiment

- Enter the desired setpoint on the computer.
- To reach the setpoint, let the pump draw water from the tank below and pump water to the same tank. Also, use the proportional valve for flow rate control.
- Determine the most appropriate controller parameters combination required by the Ziegler-Nichols method to change the controller parameters with a computer's help to reach the desired set point.

Pressure Control Experiment

- Enter the desired setpoint on the computer.
- To reach the setpoint, let the pump water from the tank below and pump water into the stainless steel tank.

- Determine the most appropriate controller parameters combination required by the Ziegler-Nichols method to change the controller parameters with a computer's help to reach the desired set point.

Temperature Control Experiment

- Enter the desired setpoint on the computer.
- To reach the setpoint, connect the heater to be controlled to 220 VAC.
- Determine the most appropriate controller parameters combination required by the Ziegler-Nichols method to change the controller parameters with a computer's help to reach the desired set point.

CALCULATIONS

The type of control to be selected (P, PI, PID) and their parameters K_c, K_R, and K_d are directly related to the process's model to be controlled. Setting the required control parameters to make the desired control is called *tuning*. The selection of controller parameters is an optimization problem that the control system designer must meet some optimization criteria. The primary criterion for reasonable control is that its response to a step change at the set point gives the minor overshoot and ¼ damping ratio. Another criterion is the least rise time and the least rest time.

One of the essential methods used in the experimental calculation of the parameters K_c, K_R, and K_d is the Ziegler – Nichols (ZN) rule. With this method developed by Ziegler and Nichols, K_c, K_R, and K_d, parameters of a closed-loop system can be adjusted. ZN did not suggest that frequency-response calculations can calculate the ultimate gain (K_{cu}) and the ultimate period (P_u) based on the process model. They suggested that K_{cu} and P_u can be obtained by testing the entire process in a closed-loop. According to this;

1. First, the parameters K_R, and K_d on the controller are disabled.
2. A proportional gain (K_c) is selected. The system is disrupted, and the response of the system is received. A small step change is given as a disturbance effect, and the response is followed. If the answer is damped before it reaches the setpoint, a higher K_c value is selected, and the system response is observed again. The increase in gain is continued in small steps to the point where the answer gives an oscillation for the first time. The oscillation begins at the gain value and oscillation period and responds to the ultimate gain (K_{cu}) and ultimate period (P_u) values.
3. The K_c and P_u values are used as data to calculate K_c, K_R, and K_d parameters.

Table 1. Ziegler-Nichols controller arrangements

Controller Type	**K_c**	**K_R**	**K_d**
Proportional (P)	0.5 K_{cu}	-	-
Proportional-integral (PI)	0.45 K_{cu}	$\frac{P_{cu}}{1.2}$	
Proportional-integral-derivative (PID)	0.6 K_{cu}	$\frac{P_{cu}}{2}$	$\frac{P_{cu}}{8}$

DISCUSSION

Liquid Level Control Experiment

- Write your data in the table below:

K_c	Setpoint	Disturbance	Measured value	Oscillation Yes / No

Find the K_{cu} value and apply the ZN rules and calculate the parameters K_R and K_d. Observe the accuracy of these values by conducting a verification experiment.

K_{cu}	K_c	K_R	K_d	Setpoint	Measured value

Flow Control Experiment

- Write your data in the table below:

K_c	Setpoint	Disturbance	Measured value	Oscillation Yes / No

Find the K_{cu} value and apply the ZN rules and calculate the parameters K_R and K_d . Observe the accuracy of these values by conducting a verification experiment.

K_{cu}	K_c	K_R	K_d	Setpoint	Measured value

Pressure Control Experiment

- Write your data in the table below:

K_c	Setpoint	Disturbance	Measured value	Oscillation Yes / No

Find the K_{cu} value and apply the ZN rules and calculate the parameters K_R and K_d. Observe the accuracy of these values by conducting a verification experiment.

K_{cu}	K_c	K_R	K_d	Setpoint	Measured value

Temperature Control Experiment

- Write your data in the table below:

K_c	Setpoint	Disturbance	Measured value	Oscillation Yes / No

Find the K_{cu} value and apply the ZN rules and calculate the parameters K_R and K_d. Observe the accuracy of these values by conducting a verification experiment.

K_{cu}	K_c	K_R	K_d	Setpoint	Measured value

QUESTIONS

1. Briefly describe the process control methods.
2. Describe the methods used to find K_c , K_R , and K_d parameters other than the Ziegler-Nichols method, and examine their advantages and disadvantages.

REFERENCES

1. Festo Didactic product user manual.
2. Coughanowr, D., *Process Systems analysis and Control*, McGraw-Hill, 1991.