CHAPTER I
INTRODUCTION

1.1 Background

A chemical plant is a series of integrated processing units that convert raw materials into products of use value. During its operation, process conditions can change due to changes in operating conditions or disturbances from the external environment. To maintain these operating conditions, continuous monitoring of the chemical plant's operation is required, along with control actions to achieve the operating objectives. This is accomplished through a series of equipment, such as measuring instruments, controllers, and computers, together with human involvement such as plant managers and plant operators, who jointly form a control system.

Process control is carried out by adjusting the operating variable based on the measured process condition. A control system generally consists of a sensor or measuring instrument, a controller, and an actuator working in an integrated manner to maintain the process variable at the desired value (set point). In a feedback control system, the actual process condition is measured and compared with the set point to produce an error. This error is then used by the controller to determine the control action so that the system response can be corrected in response to changes in process conditions (Liu et al., 2023).

One important process variable to control is the level, or the height of fluid in a tank. Level control is required to keep the tank's operating condition within the desired range and to maintain the balance between inflow and outflow. One control method that can be used is PID (Proportional Integral Derivative) control, which operates based on three control parameters: proportional band, integral time, and derivative time. Changes in these parameters can affect the system's response characteristics, such as response speed, overshoot, and system stability. Therefore, an understanding of the operation of a level control system and the effect of control parameters on the system response is needed to understand the application of process control in industry.

1.2 Problem Statement

In industrial production processes, control of process variables is required to maintain operational stability, safety, quality, and efficiency. This control is carried out by monitoring process conditions and adjusting operating variables so that they remain within the desired conditions. One important variable that must be controlled in industrial processes is level (fluid height), because changes in level can affect the operating condition of a process unit. Therefore, this practicum was conducted to examine the operation of a level control system using the PCT 50 Level Control, the effect of the operating mode on the time required to reach the maximum level, and the effect of changes in proportional band, integral time, and derivative time on the system response.

1.3 Objectives of the Practicum

1. To be able to operate a process using a control system.
2. To be able to evaluate a process with variations in the feedback controller (Proportional (P), Proportional Integral (I), and Proportional Integral Derivative (PID)).
3. To be able to examine the graph of the relationship between level and elapsed time with respect to set point, sampling interval, and PID.

1.4 Benefits of the Practicum

1. Students are expected to be able to understand the operation of a process using a control system.
2. Students are expected to be able to evaluate a process with variations in the feedback controller (Proportional (P), Proportional Integral (I), and Proportional Integral Derivative (PID)).
3. Students are expected to be able to examine the graph of the relationship between level and elapsed time with respect to set point, sampling interval, and PID.

CHAPTER II
LITERATURE REVIEW

2.1 Process Control

A control system is an arrangement of physical components designed to control a system associated with a process, either in an open-loop or closed-loop state (Benner, 1993). An open-loop system is a control system that does not use feedback from the process output to determine the control action. In contrast, a closed-loop system uses feedback from the process output to be compared with the set point. The difference between the actual value and the set point is called the error, which is used by the controller to determine the control action. Thus, a closed-loop system can correct for changes in process conditions. This control principle is then applied in process control, namely controlling one or more quantities so that they remain at a certain value or range. For example, the fluid level in a reactor must be maintained at a certain value, which requires a control valve to regulate the amount of flow entering the reactor.

In a closed-loop control system, there are several main components that are interrelated, namely the controller, actuator, plant, and sensor. The controller functions to determine the control action based on the difference between the set point and the output value, while the actuator converts the control signal into an action on the process. The plant is the process being controlled, while the sensor measures the process output and sends a feedback signal to the controller.

There are various process parameters that need to be controlled to keep the process running according to the desired conditions. Among the most common are pressure in pipes and reactors, flow in pipes, temperature in process units such as heat exchangers, or the level of liquid in a tank, and the concentration of chemicals (Dong et al., 2024). In addition, there are several other parameters beyond these four that are quite important and also need to be controlled due to specific process requirements, including: pH in the petrochemical industry, water cut (BS & W) in crude oil fields, product color in a natural gas liquids (NGL) facility, and so on.

In practice, automatic control systems play an important role because they can improve the performance of dynamic systems, improve product quality, reduce production costs, and increase production speed. The role of the manual operator has now largely been replaced by a device called a controller. For example, the task of opening and closing a valve can be performed automatically using a controller. To be controlled automatically, the valve is equipped with an actuator so that it functions as a control valve within the process control instrumentation system.

One commonly used control method is PID (Proportional Integral Derivative) control. PID control functions to improve system performance by enhancing the response to changes in conditions. With the application of PID control, the system can reduce or even eliminate steady-state error and increase the speed of response in reaching the desired set point.

2.2 Proportional (P) Control

Proportional control is a controller whose output signal (p(t)) is proportional to the error (e(t)), i.e., the difference between the set point and the measured result, which can be mathematically expressed as follows:

$$p(t) = \bar{p} + K_p \times \text{error}(t) \tag{2.1}$$

Based on this approach, Kp is the proportional gain, which indicates the responsiveness of the controller to the process setup, or the correction given to reach the set point. The proportional gain is adjusted to determine how responsive the system is to the difference between the set point and the process variable.

A proportional controller has two parameters: the proportional band and the proportional constant. The effective operating range of the controller is reflected by the proportional band, while the proportional constant indicates the gain factor applied to the error signal, Kp. The relationship between the proportional band (PB) and the proportional constant (Kp) is shown as follows:

$$PB = \left(\frac{1}{K_p}\right) \times 100\% \tag{2.2}$$

This control system is a very simple form of process control, with a very fast response to the set point and process disturbances, but it has a large steady-state error characteristic.

Characteristics of the proportional controller:

1. If the value of Kp is small, the proportional controller provides a small error correction, so the system response becomes slower and the rise time increases.
2. If the value of Kp is increased, the proportional controller provides a larger correction, so the system response becomes faster and the rise time decreases.
3. If the value of Kp is too large, the system becomes unstable, marked by the occurrence of oscillation or overshoot.

4. The value of Kp can be adjusted to reduce the steady-state error, but it cannot eliminate it entirely.

2.3 Integral (I) Control

Integral control functions to eliminate error entirely, especially steady-state error. The main purpose of the integral component is to ensure that the error between the set point and the system output becomes zero. It works by continuously calculating the error over time, then summing it (integrating) to produce a control signal.

$$p(t) = \bar{p} + K_i \int_0^t \text{error}(\tau)d\tau \tag{2.3}$$

By integrating the error, the system's output value can be corrected cumulatively, especially when the error persists over a long period. However, integral control is rarely used on its own because it has several drawbacks. One common problem that arises is reset windup, a condition in which the accumulated error causes the control signal to exceed the capability of the control valve, which is already saturated (fully open), so the system no longer responds to control commands. This can cause overshoot or even cause the controller to lose its function as a controller. To address this, additional methods such as anti-reset windup are typically used to keep the system response stable and controlled.

2.4 Derivative (D) Control

Derivative control functions to anticipate an error that is about to occur by observing the rate of change and predicting the change, so that the system reacts more quickly and intelligently to changes. The derivative controller is known for its rate action, pre-act action, or anticipatory control. Its function is to anticipate the behavior of the error signal that is about to occur by observing the rate of change and predicting the change. The derivative controller can speed up the system response, thereby reducing overshoot (the signal exceeding the set point).

$$p(t) = \bar{p} + K_d \frac{d\,\text{eror}(t)}{dt} \tag{2.4}$$

The derivative controller helps the system respond more quickly at the start and prevents the signal from exceeding the desired value (set point). It works by observing how fast the error changes. If the error increases rapidly, the controller will react immediately before the error becomes too large. Conversely, if the error decreases rapidly, the controller will reduce its reaction so that it does not decrease excessively. As a result, the system becomes more stable, less likely to exceed limits, and reaches a stable condition more quickly.

2.5 Proportional Integral (PI) Control

A PI controller is a control system that combines proportional and integral control. Integral control is used to eliminate error by integrating the error over a certain period until the error becomes "zero," or there is no error at all. The controller's output form depends on the integral of the error signal over the entire time period, where:

$$\Delta Q_{output} = K_i \int i.\ Dt \tag{2.5}$$

atau

$$p(t) = \bar{p} + K_p(eror(t) + \frac{1}{\tau_i}\int_0^t eror(\tau)d\tau) \tag{2.6}$$

K_i = integral gain or "reset rate" (repeat/minute)

K_p = the magnitude of correction applied

τ_i = integral time, or reset time

Integral control is also known as "reset," which has a relatively slow response but is quite effective for controlling processes that occur quickly, contain significant disturbances, and are dominated by deadtime in product transport. Its effect on steady-state error is relatively small. This control is commonly used to reduce the offset between the set point and the process variable.

2.6 Proportional Integral Derivative (PID) Control

Proportional Integral Derivative (PID) control is a type of control system that combines three different control elements, namely proportional, integral, and derivative. This PID control is used to determine the values of Kc, τi, and τD. The derivative control is generally also known as "rate." The value of this parameter essentially represents how far ahead, in seconds, it seeks to predict the rate of change. The model equation used is:

$$\Delta Q_{output} = K_d \frac{d\,error(t)}{dt} \tag{2.5}$$

Atau

$$p(t) = \bar{p} + K_p(eror(t) + \frac{1}{\tau_i}\int_0^t eror(t_i)dt_i + \tau_D \frac{d\,error\,(t)}{dt}) \tag{2.6}$$

K_d = time constant

τ_D = derivative time

The derivative model never stands alone but is always combined with proportional or proportional-integral control, because derivative control only responds when there is a change in the error, so when the error is static (constant), this control will not react. In PID control, there are three parameters that can be adjusted: Kp, τi, and τD. In PID control itself, the occurrence of derivative kick (a large disturbance) must be avoided by adjusting the available parameters.

2.7 Ziegler-Nichols Method

Tuning is the process of adjusting the parameter values in a controller, such as PID (Proportional, Integral, Derivative), so that the system can operate properly as desired. In a control system, tuning is very important because it determines how quickly, stably, and accurately the system responds to changes or disturbances. If tuning is done correctly, the system will respond quickly without excessive oscillation, will not be too slow, and will be able to reach the target or set point efficiently. This tuning process is usually carried out by trial and error of parameter values, using mathematical methods, or using an experimental approach, depending on the type of system and the information available.

One tuning method used is the Ziegler-Nichols method. The Ziegler-Nichols method is a practical way to tune a PID controller so that the system can operate quickly and stably, without needing to know the formula or mathematical model of the system. This method is carried out by observing how the system responds when its input is changed, and from these observations, the appropriate PID parameter values are determined. The goal is for the system to produce a fast and stable response, with an overshoot value of around 25%. Because the method is simple and does not require complex calculations, it is very useful in various industrial fields, such as temperature, pressure, and flow regulation, or other automatic systems that require a fast and efficient response.

The Ziegler-Nichols method for a PID controller begins by setting the controller's integral (Ki) and derivative (Kd) values to zero, leaving only the proportional gain (Kp) active. Then, the value of Kp is gradually increased until the system begins to show unstable oscillatory behavior. The value of Kp at the point where the system oscillates is called KMAX (the maximum value at which the system can still operate but has begun to oscillate). During oscillation, the frequency that forms is called f0. After reaching KMAX, the value of Kp is reduced to a lower level, typically set at around 50-75% of KMAX. Finally, the value of f0 is used to determine the integral (τi) and derivative (τD) gain values based on the formulas established by Ziegler-Nichols. In general, the formulas for setting the PID parameters are as follows:

$$K_p = 0{,}6 \text{ x } K_{MAX} \tag{2.9}$$

$$T_i = \frac{1}{2 \text{ x } f_0} \tag{2.10}$$

$$T_d = \frac{1}{8 \text{ x } f_0} \tag{2.11}$$

(Ellis, 2012)

2.8 PCT 50 Level Control

Figure 2.1 PCT 50 level control

The PCT 50 is a level control device that uses water as the working fluid. Water from the lower reservoir tank is delivered to the upper process vessel using a centrifugal pump with adjustable speed. At the pump's outlet line, there is a quick-release connector that allows the hose to be easily disconnected and reconnected. This connector is used to facilitate the priming process, i.e., filling the pump and its lines with water before the pump is operated. The inlet line to the process vessel is designed vertically so that the incoming water flow can still be observed at various water levels. In addition, there is a check valve that functions to prevent water from flowing back to the lower reservoir tank when the pump is slowed down or stopped. A ball valve (CV1) is used to manually regulate the amount of water flowing into the process vessel, allowing the flow condition to be adjusted according to the needs of the experiment.

The water level in the process vessel is measured using an electronic pressure sensor mounted at the bottom or side of the vessel. One side of the sensor is connected to the interior of the vessel, while the other side is open to the atmosphere. The pressure difference between the water inside the vessel and the atmospheric pressure is used to determine the water level. In addition to using the pressure sensor, the water level can also be observed via the scale located on the side of the process vessel. After being in the process vessel, water flows back to the lower reservoir tank through two outlets located at the base of the vessel. One outlet discharges water continuously, while the flow at the other outlet can be regulated using a remotely controlled solenoid valve (SOL). Both outlets are equipped with ball valves (CV2 and CV3) to manually regulate the flow rate.

In addition to the ball valves, both outlet lines are equipped with orifices that can be used to set the flow rate under certain conditions. An orifice is a hole of a certain size that functions to restrict water flow. The orifice size can be changed as needed by removing the plastic cover and replacing it with the desired orifice size. This replacement is done manually using an O-ring seal and can be tightened by hand. Orifices of other sizes are stored at the front of the device's base plate when not in use.

The process vessel is also equipped with an overflow line that functions to return excess water to the lower reservoir tank, thereby preventing the process vessel from being overfilled. The pressure sensor, centrifugal pump, and solenoid valve are connected to an electrical interface, which functions to process the signals from each component so that the system can be operated via computer using a single USB connection. The PCT 50 software can be used to control the level directly while simultaneously recording the system's response during the experiment. In addition, the software can be used to record data when the system is operated using the PID controller. Thus, the PCT 50 can be used to study the characteristics and response of a level control system to changes in operating conditions as well as control parameters.

CHAPTER III
PRACTICUM METHOD

3.1 Practicum Design

3.1.1 Practicum Design

Figure 3.1 Rancangan praktikum

3.1.2 Variable Determination

3.2 Materials and Tools Used

3.2.1 Materials

Aquadest 8 liters

3.2.2 Tools

PCT 50 Level Control

3.3 Picture of The Tools

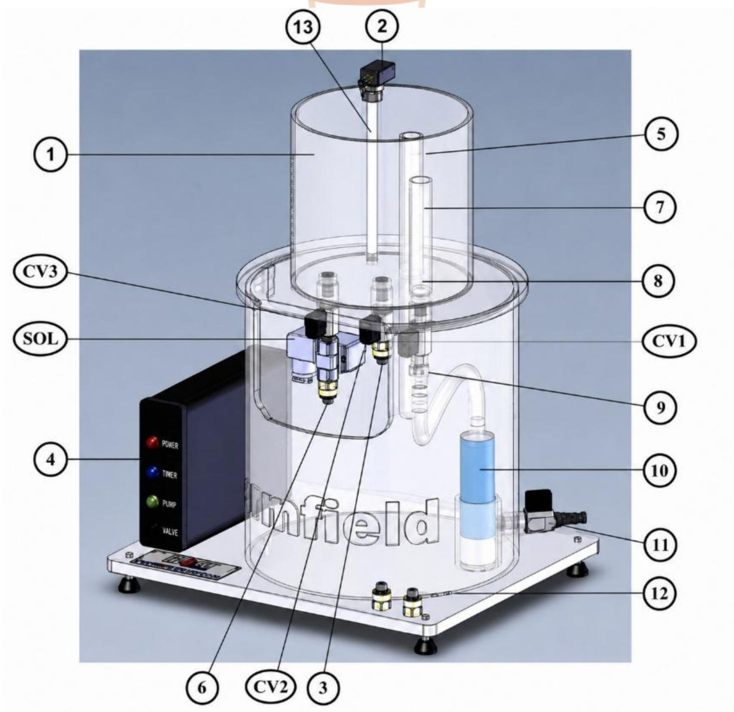

Figure 3.2 PCT 50 level control device and its components

(1) Upper Process Vessel	(9) Quick Release Connector
(2) Level Sensor	(10) Centrifugal Pump
(3) Manual Discharge Port	(11) Water Discharge
(4) Electrical interface	(12) Alternative sizes of orifice
(5) Solenoid Discharge Port	(CV1) Control Valve 1
(6) Overflow	(CV2) Control Valve 2
(7) Inlet	(CV3) Control Valve 3
(8) Integral non-return valve	(SOL) Solenoid Drain Valve

3.4 Procedure

3.4.1 Installing Software Armfield Level Control

1. Install the driver first by going to This PC, right-clicking, selecting Properties, and then selecting Device Manager.
2. Plug the USB into the laptop; COM 5 will appear with an exclamation mark. Make sure the PCT-50 is switched on, indicated by the green light.
3. Remove the exclamation mark by updating the driver. Find the PCT-50 folder, select the second icon from the top, then install by following the steps in the driver installation. The laptop will restart automatically once the installation is complete.
4. Make sure the USB is properly connected so that the connection between the PCT-50 device and the laptop does not suddenly disconnect. Also make sure the device is not in scanning mode when it is about to be used..

3.4.2 Conducting the Practicum

a. Calibration of the PCT-50 device

1. Make sure the drain valve at the back of the reservoir tank is tightly closed, then fill the lower reservoir tank with 8 L of distilled water below the opening at the front of the tank.
2. Make sure the sensor is empty before each practicum session. If water is trapped in the sensor, use a glass brush to ensure the sensor is empty.
3. Make sure the flow control valve CV1 is fully open at the inlet of the process vessel so that distilled water can flow into the vessel while the pump is running.
4. Make sure the outlet valve CV2 is fully open at the base of the process vessel to allow distilled water to return to the reservoir tank as the process vessel fills with distilled water.
5. Make sure valve CV3 is fully open above the solenoid valve SOL to allow distilled water to return to the reservoir tank when the solenoid valve opens and the process vessel is filled with distilled water.
6. Turn on the pump and make sure distilled water can flow into the process tank. If it does not flow, disconnect the upper pump hose and fill it with distilled water by submerging it in the distilled water in the reservoir tank.

7. Once distilled water can be pumped smoothly into the reservoir tank, empty the process tank and carry out the experiment according to the specified variables.

b. Finding the maximum level
   1. Make sure the process tank is empty.
   2. Set the sample interval and fixed duration in the sample configuration menu according to the specified variables.
   3. Set the variables (pump speed, set point, proportional band, integral time, derivative time, and mode of operation) that have been determined in the PID menu.
   4. Operate the device according to the specified variables by clicking power on and then go to record the data obtained.
   5. Observe the resulting graph in the graph menu, then collect and save the practicum data in accordance with the data shown in the PCT-50 application (Excel).
   6. Once the desired time has been reached, reduce the pump speed to return the water to the tank.
   7. Repeat steps 2-6 with a different variable (operating mode).

c. Determining PID values and the effect of PID parameters
   1. Make sure the process tank is empty.
   2. Set the variables (pump speed, set point, proportional band, integral time, derivative time, and mode of operation) that have been determined in the PID menu.
   3. The operating mode is set to automatic.
   4. Operate the device according to the specified variables by clicking power on and then go to record the data obtained.
   5. Observe the graph, then collect and save the practicum data in accordance with the data shown in the PCT-50 application (Excel).
   6. Repeat steps 2-6 by varying one of the PID parameters (proportional band, integral time, or derivative time) according to the specified variables, while keeping the other PID parameters constant.
   7. Once all steps have been completed, clean the device by opening the drain valve so that the water in the tank drains out; make sure the water in the tank and process vessel is completely gone.

8. After cleaning and drying, the device can be switched off gradually.

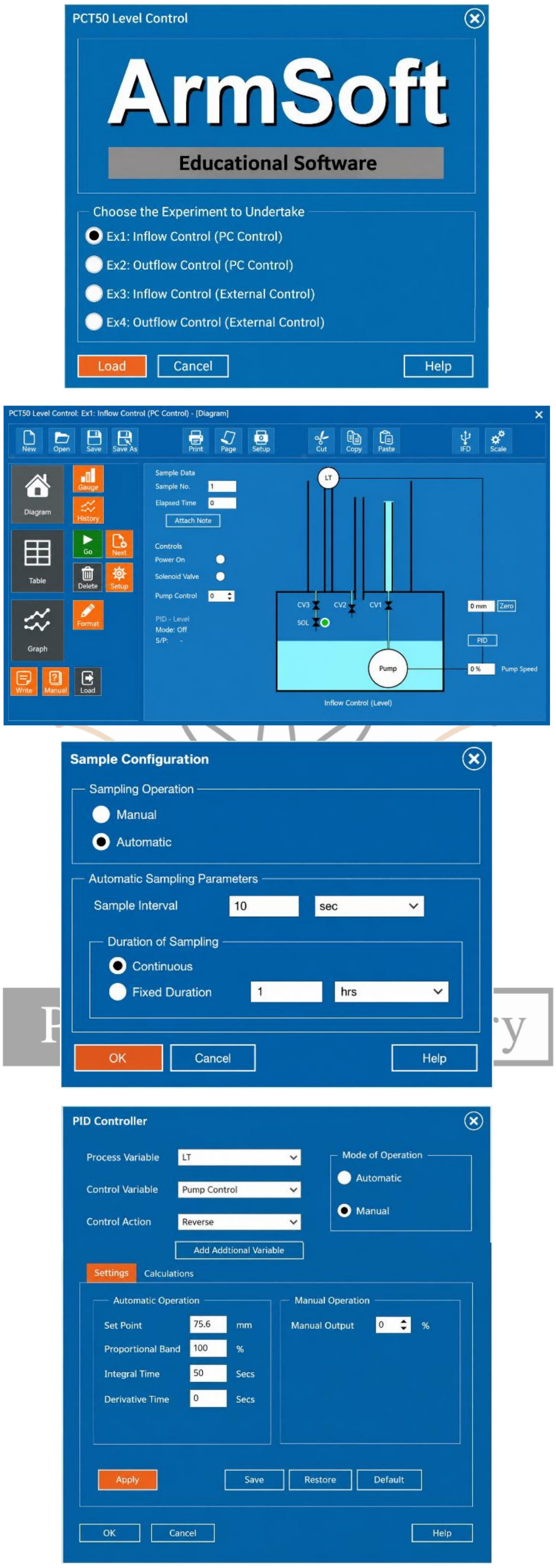

Figure 3.3 Steps for using the Armfield PCT 50 software