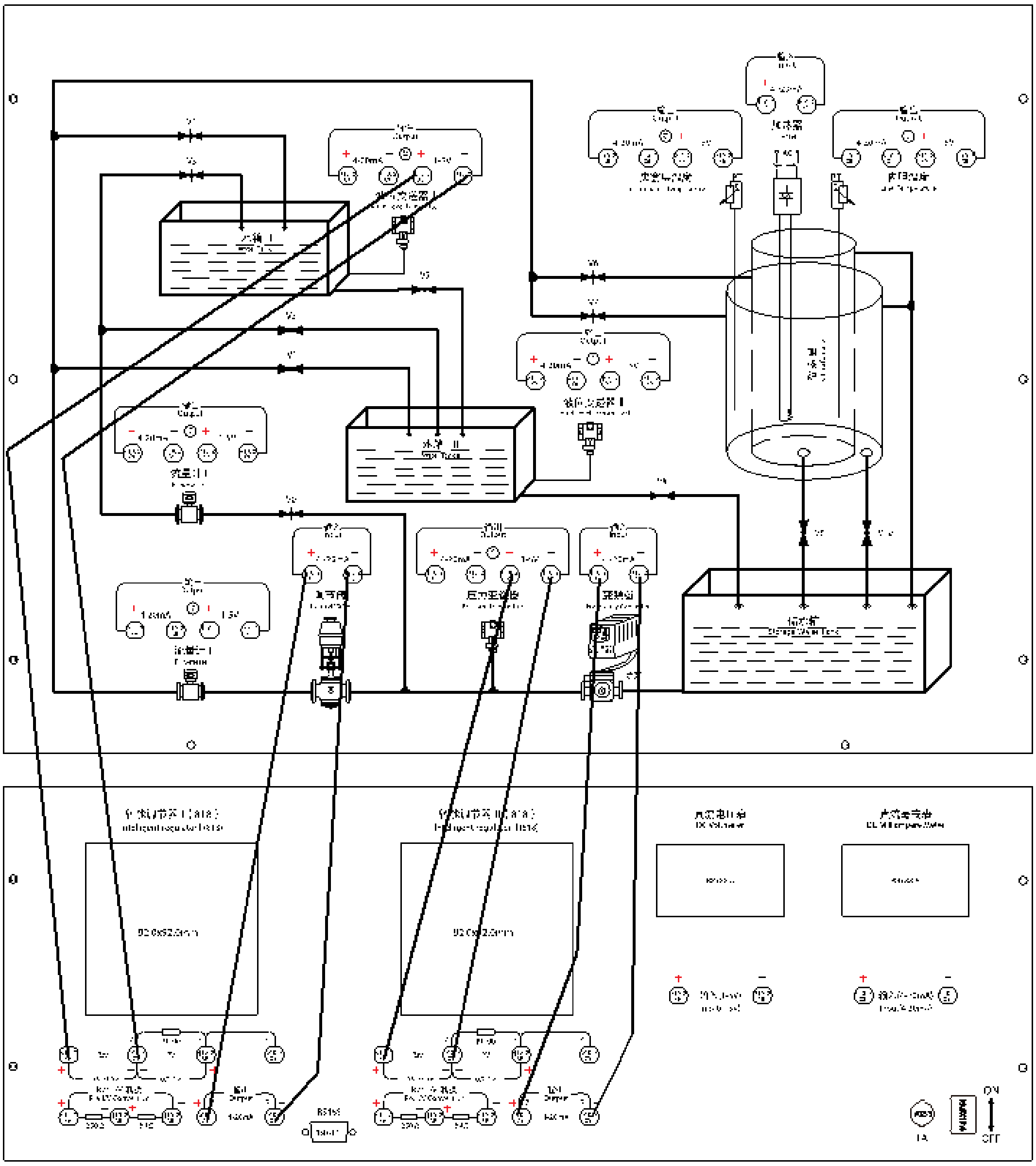
Experiment 5: Modeling of Single-Volume Water Tank Characteristics

1. Experimental Objective：

To understand the function and operation methods of the regulator, and to learn how to use the regulator. Through the experiment, to understand the ideology and methods of measuring object characteristic curves, and to master the methods of obtaining object model parameters.

2. Experimental Equipment:

Water pump, frequency converter, pressure transmitter, regulator I (Model 818), main circuit regulating valve, upper water tank, upper water tank level transmitter, regulator II (Model 818), ammeter.



3. Experiment Principle：

By conducting a simple test to obtain the step response of the controlled object and further fitting it into an approximate transfer function, we can establish a simple and effective mathematical model of the controlled object.

To establish the mathematical model of the controlled object using the test method, we first need to select the structure of the model. The transfer function of typical industrial processes can take various forms, such as:

（1）First-order Inertial Link with Pure Delay

The transfer function of a first-order inertial link is:

$$G(s) = \frac{K}{Ts+1}$$

The transfer function of the delay link is:

$$G(s) = e^{-\tau s}$$

Transfer Function of a First-order Plus Pure Lag Object

$$G(s) = \frac{Ke^{-\tau s}}{Ts+1}$$

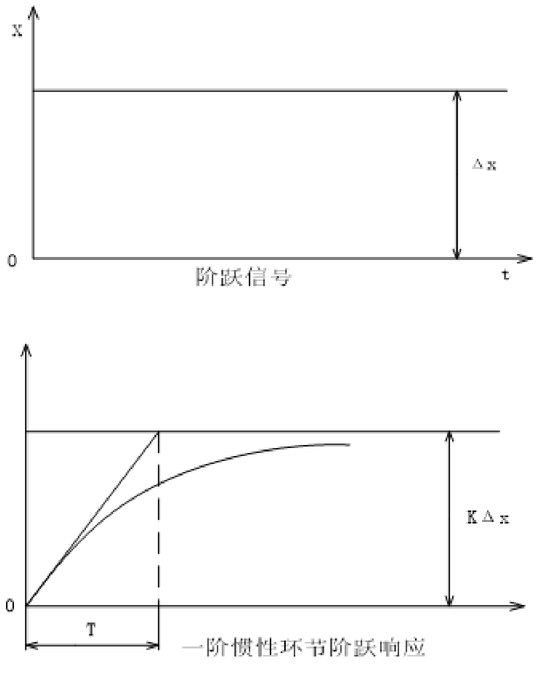


Figure 4-1

For a first-order object with pure lag, the lg time can be directly measured from the figure, as indicated by τ.

（2）Second-order or higher-order inertial link with pure delay

$$G(s) = \frac{Ke^{-\tau s}}{(Ts+1)^n}$$

Once the form of the transfer function is determined, each parameter in the function needs to be fitted with the response curve obtained from the test. If the step response is a monotonically increasing curve, such as the S-shaped curve shown in Figure 3-2, it can be fitted using the transfer function of a first-order inertial link with pure delay. The gain K can be directly calculated from the steady-state values of the input and output, while τ and T can be determined using graphical methods.

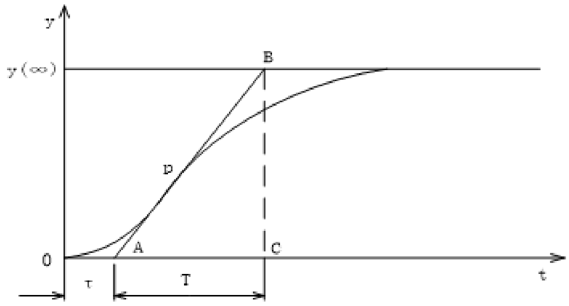


Figure 4-2

In Figure 4-2, at the inflection point p of the curve, draw a tangent line, which intersects the time axis at point A and intersects the steady-state asymptote of the curve at point B. The value of segment 0A represents the pure lag time τ, and the value of segment CB represents the time constant T. This determines the numerical values of τ and T, as shown in Figure 3-2.

（3）Calculation of Amplification Factor K

The definition of the amplification factor K is:

$$K \overset{def}{=} \frac{输出量稳态值}{输入量}$$

Equivalently：

$$K = \frac{\Delta Y/(Y_{MAX} - Y_{MIN})}{\Delta X/(\Delta X_{MAX} - \Delta X_{MIN})}$$

ΔX	The change in regulator output current, unit: mA.
XMAX	The upper limit value of regulator output current, unit: mA.
XMIN	The lower limit value of regulator output current, unit: mA.
ΔY	The change in liquid level, unit: mm.
YMAX	The upper limit value of liquid level, unit: mm
YMIN	The lower limit value of liquid level, unit: mm

Example 1: In the experiment, the regulator output current increases from 8mA to 12mA, and the liquid level rises by 0.4mm. Calculate the amplification factor K

ΔX=12-8=4mA

ΔX/(XMAX-XMIN)=4/(20-4)=0.25

ΔY/(YMAX-YMIN)=0.4

We can know：K=0.4/0.25=1.6

The above formula is only applicable to self-balancing processes. For non-self-balancing processes, their transfer function should include an integral link. For liquid level control systems, the liquid level object is a self-balancing object, and a single tank alone is a first-order object. The upper water tank and the middle water tank can form a second-order object.

4. Experiment Procedure:

Familiarize yourself with the experimental system and understand the various components within it. Learn the names, basic principles, and functions of each instrument in the experimental system, and master their correct wiring and usage methods to ensure accurate and proficient operation of the instruments for data retrieval during the experiment. Familiarize yourself with the panel diagram of the experimental setup so that you can locate each instrument based on its graphical and textual symbols. Understand the structure of the system and the pipeline, and identify the positions and functions of manual valves.

This experiment utilizes manual output control of the regulator to control the regulating valve, with data being collected and recorded by the computer. The flowchart is shown in Figure 4-3.

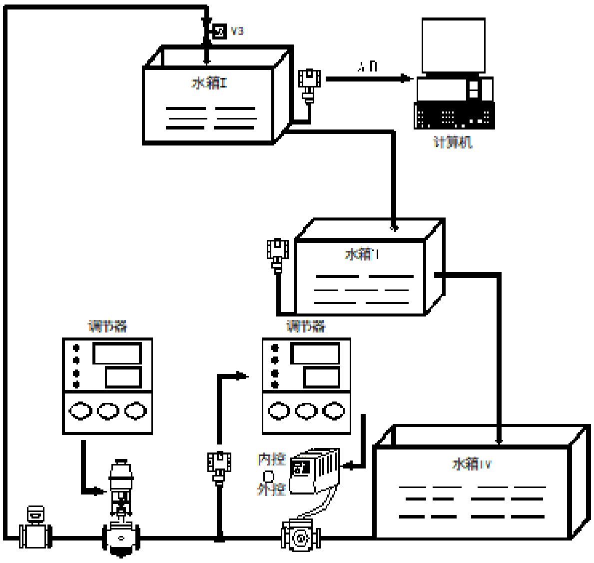


Figure 4-3- The process for the upper water tank characteristic test (regulator control) is as follows

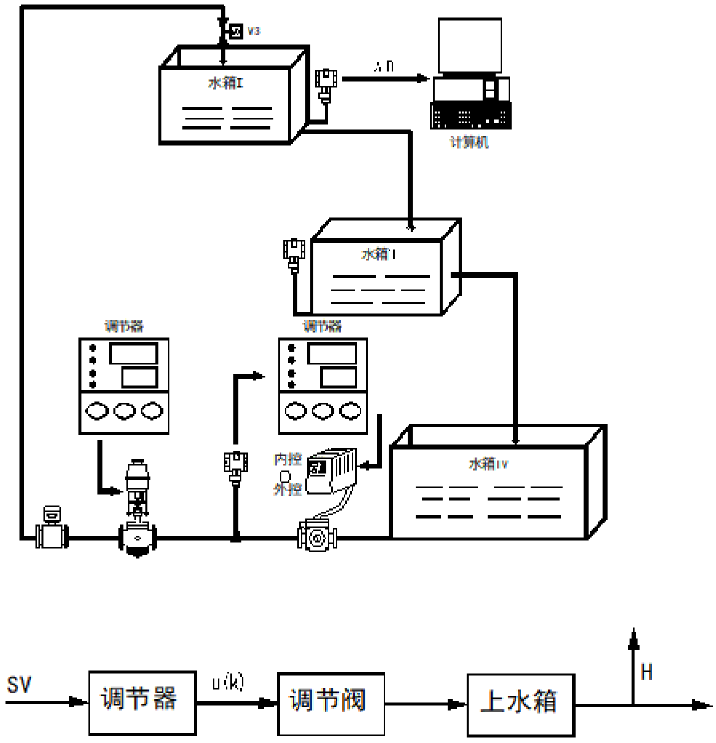


Figure 4-4- a The system diagram for the upper water tank characteristic test (regulator control) is as follows

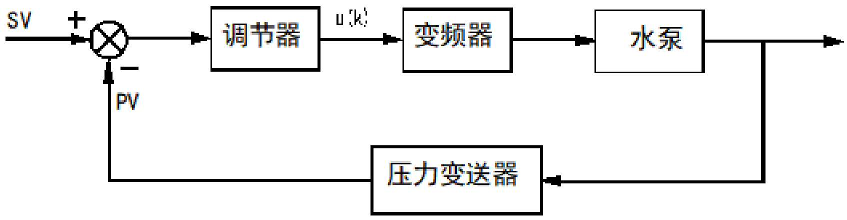


Figure 4-5- b Constant-pressure water supply (regulator control) system diagram

（1）Wire the equipment used in the upper water tank characteristic test (regulator control) experiment according to the flowchart and system diagram.

（2）After confirming that the wiring is correct, power on and open the hand valves V4, V5, and V8, with the opening of valve V8 > V4 > V5.

（3）Turn on the power of the frequency converter, with the power indicator light on. Set the frequency converter to internal control by turning the internal/external control switch.

（4）Once the constant-pressure water supply stabilizes, set the parameters of the level regulator and use the manual output function. (Note: When changing the regulator parameters, do not use fingernails to press the buttons on the regulator panel to prevent damage to the buttons. Use fingers evenly with force.)

（5）Increase the manual output of the regulator using the increase/decrease keys and provide an appropriate step signal to the system (avoid using a step signal that is too large) to induce changes in the system output and reach a new equilibrium state at a higher liquid level.

（6）Observe the step response and historical curve of the upper water tank liquid level collected by the computer.

(7) Return the manual output of the regulator to its original value and record the curve of the liquid level decreasing.

(8) Analyze and process the curves. Analyze and process the recorded curves of the experiment separately, and record the processing results in Table 4-1.

Table 4-1 Step Response Curve Data Processing Record

Values / Measurement	Liquid Level		
	K	T	τ
Forward Input			
Reverse Input			
Average Value			

5. Experiment Report:

Based on the experimental results, write the experimental report, calculate the average values of K, T, and τ, and derive the system's generalized transfer function (equivalent to an inertial link, where K is the static gain, T is the time constant, and τ is the delay time).