MT-318 INTRODUCTION TO INDUSTRIAL PROCESS CONTROL

CEP REPORT

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1. INTRODUCTION

CONTEXT:
We are provided with the scenario of household water storage system. We will use this scenario as our case study to build an automatic industrial process control system. In a process control, we first observe some regulatory parameter and compare it to the desired value we want to achieve. Some control action is initiated for the difference encountered by using some controller. In this way the parameter is set closest to the attainable desired value.

PROCESS:
We designed an industrial process control which is an automated control system. In this way it will work more efficiently.

Process control is the automatic control of an output variable by sensing the amplitude of the output parameter from the process and comparing it to the desired or set level and feeding an error signal back to control an input variable. [1]

PROBLEM:
The water reservoir, having volume V, at ground level is filled with water from a government source that has a random flow rate F1. Additionally, a water bore is also available that supplies water to the reservoir at a fixed rate of F2 and can be turned on or off as required. The water is pumped at a fixed flow rate, F3, from the reservoir to a tank whose level should be maintained above the low level lsp. The tank's volume is 1/3rd the volume of the reservoir and is located at height ′h′ from the reservoir. The tank has an outflow, F4, that depends on the load. It is further required that an empty tank should be filled within 10 minutes. You are required to design a comprehensive process control system to automate the whole process.

SOLUTION METHODOLOGY:
Firstly, we have water reservoir with three set points. Low-level at the bottom, mid-level at the half and high level at the top of the reservoir. Water pumped from the bore will continue to fill the reservoir up till mid-level. If water is coming from a government source with random flow rate, then the reservoir will be filled up till the maximum level and after reaching that point, the float that is attached which will turn the valve off.

Secondly, we have tank with two set points. Low-level and max-level. Water coming through the pipe from reservoir to the tank has fixed flow rate which we have to maintain. Motor will be turned on at the low level and we will measure the flow from the pipe and to maintain this flow rate (6.17 gallons/s through calculations) we will control the valve. The tank will be filled in 9 minutes.

BLOCK FLOW DIAGRAM:

Block Flow Diagrams shows the basic structure of the system. Figure 1.1 shows the basic block diagram of the process of our water storage system in household.

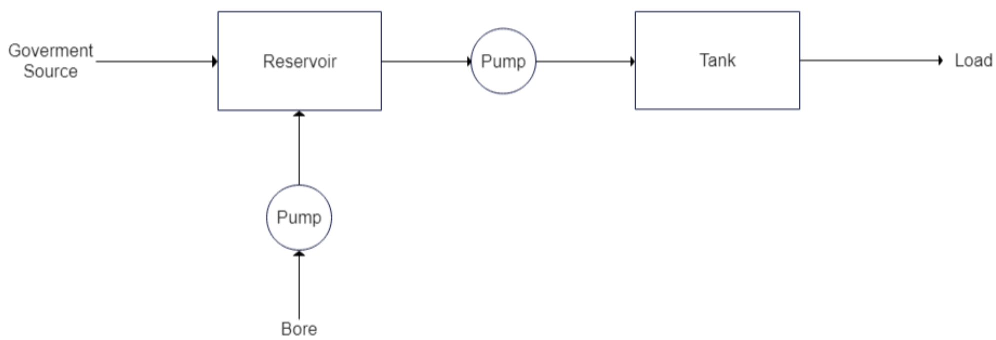

Figure 1.1

2. PARAMETERS AND CALCULATIONS

Reservoir Volume (vertical water storage tank) = 10,000 gallon

Size (vertical water storage tank) = 144 inches diameter × 161 inches height

Diameter of pipe = 4 inches

$$Reservoir\ volume\ V = 10000\ gallons$$

$$Tank\ volume\ V_T = \frac{1}{3}V = \frac{1}{3} \times 10000 = 3333\ gallons$$

$$Time\ t = 9\ minutes = 540\ seconds$$
$$(9\ mins\ to\ compensate\ any\ error\ and\ fill\ the\ tank\ under\ 10\ minutes)$$

$$Volume\ Flow\ rate\ Q = \frac{V_T}{t} = \frac{3333}{540} = 6.17\ Gallons/s = 1425.3\ in^3/s$$

$$Pipe\ diameter\ d = 4\ inches$$

$$Area = \frac{1}{4}\pi d^2 = \frac{1}{4}\pi(4)^2 = 12.57\ in^2$$

$$Velocity\ v = \frac{Q}{A} = \frac{1425.3}{12.57} = 113.39\ in/s$$

The velocity calculated is attainable. So, we have considered pipe having diameter 4.5 inches from which we can pump water at 114 inches/s. The diameter of the pipe is greater than the one in calculations because we will also control flow using control valve then we can produce excess flow rate if required.

- **Why 10,000 gallons?**
  In general, we recommend that water storage tanks should be sized large enough to meet local fire code requirements plus an additional 2 days of water supply for your irrigation and household needs. The average American household with water efficient appliances uses, on average 70 gallons per person per day. A family of 4 would use about 250 gallons per day on average. If you want to do a bit more precise calculation of your family's water usage with landscaping, check out this handy water usage calculator! Napa County requires rural homes that are not within reach of a city fire hydrant to have 2500 gallons of dedicated fire storage. New homes are required to have an additional ~800 gallons of water available for the fire sprinkler system. Right off the starting line a 3300-gallon tank is the minimum to build a new house in Napa County if you are outside of the city limits. This doesn't account for any actual water use for the house or landscaping because you don't want to be dipping into your dedicated fire supply! With the above requirements in mind, we recommend a 5000 gallons of water storage as a baseline, leaving 1700 gallons of water as a buffer for watering the yard and household uses. For large properties with significant landscaping and a large home we recommend a minimum of 10,000 gallons. [2]

3. ESSENTIAL ELEMENTS OF PROCESS CONTROL

- **Process:** A process consist of assembling of equipment used in a process. In our case, we have used water reservoir with two inlets from which water from government source and bore is coming. We have water tank with one inlet through which water from reservoir is pumped. Figure 1.2 shows basic process diagram.

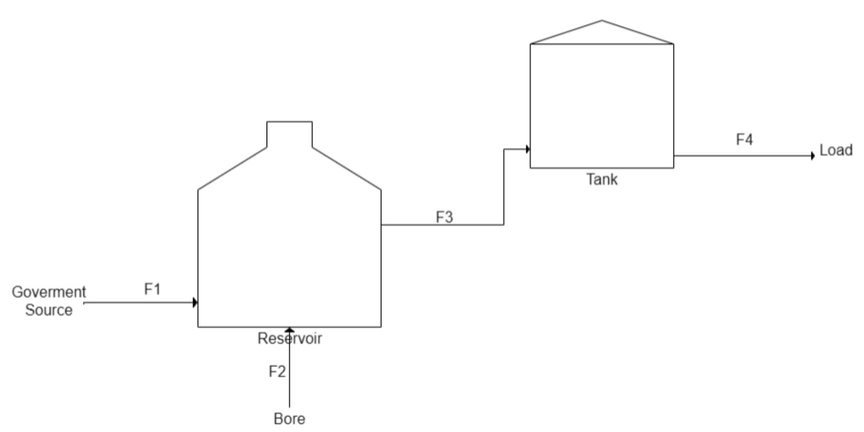

Figure 1.2 Process diagram

Measurement: In our control system, to measure variables we use different sensors. In our process we have used flow sensor, level sensor for tank and reservoir and pressure sensor.

Evaluation: In evaluation, we compare the value measured to the set point. With the help of the controller, we can determine the amount of corrective action needed. In our process, we have used flow indicating controller and level indicating controller.

Control: The control elements accept the input from the controller and perform the action. In our process valves and pumps are the control element to control the flow rate and pump water respectively.

Manipulated variable is the input parameter that can be varied to control the measured variable.

Disturbances are the affects on the process that drive the controlled variable away from the set point.

Controlled variable is the output variable that is the given set point.

	Manipulated variable	**Disturbances**	**Controlled Variable**
Reservoir	F_2 i.e., water coming from bore	F_1 i.e., water coming from government source	Height
Tank	Position of valve and power of motor	F_4 i.e., load	F_3 i.e., flow rate and height

4. CONTROL STRATEGY

Keeping in view the given scenario, we have used feedback control.

WHY FEEDBACK CONTROL STRATEGY AND ITS WORKING:

We have used feedback control because the main disturbance in the whole process is load F_4. Compared to the load the volume of the tank is much greater so the disturbance will have very minute effect on the tank. That's why we don't have to measure the disturbance necessarily.

Secondly, disturbance is controlled when we have to maintain quality of manufactured product. Our goal is to maintain the height of water within given time in the tank to control our process.

The sensor attached with the tank will sense the height that is output and the signal sent to the feedback controller which will perform the necessary action required to bring the value as close as possible to the desired value.

CONTROL LOOP DIAGRAM

Figure 1.3 and 1.4 shows the feedback control loop diagram of the reservoir and the tank respectively.

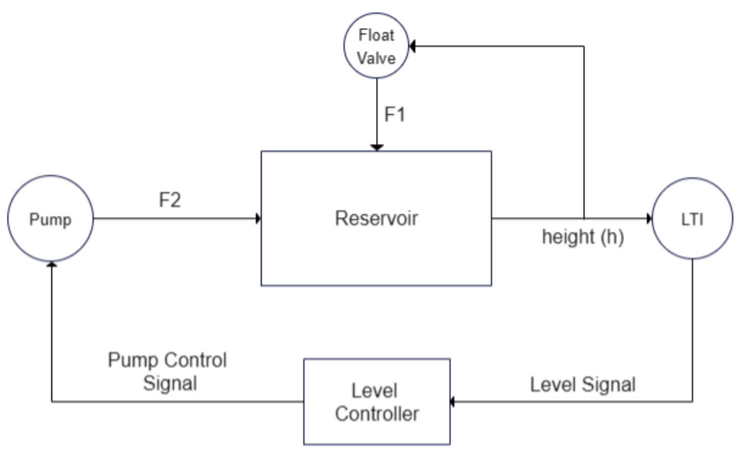

Figure 1.3 Feedback control loop for reservoir

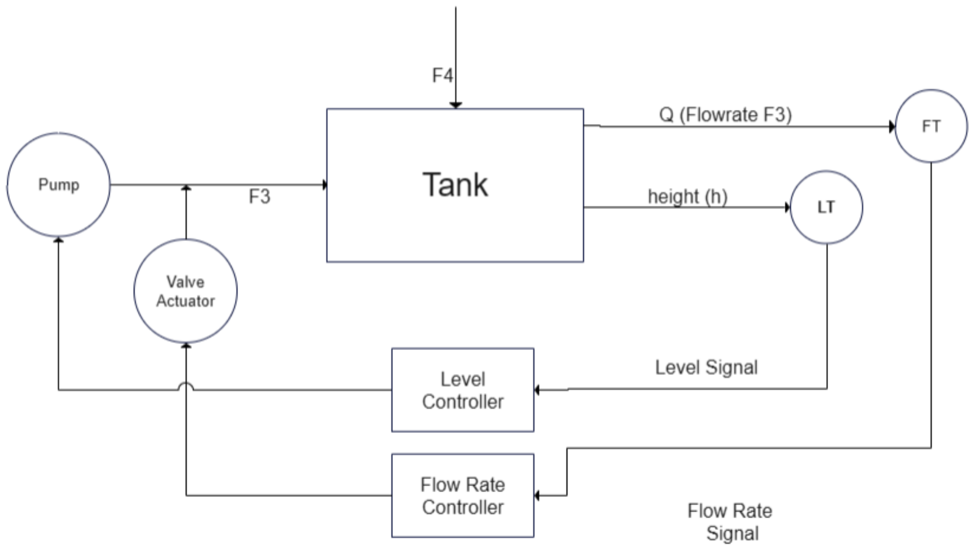

Figure 1.4 Feedback Control loop for tank

CONTROL HIERARCHY

The control type is both SCADA and Distributed Control System because to every valve or sensor there is a controller which further reports to the main controller which sends data to the consumer. That consumer can control or change data by using smartphone.

Distributed Control system is a multiple controller system that means people or controller in different areas can control the domain specific system. Tanks are installed in various different household that are controlled by different people. SCADA is a system where plant is in one place and controlling is done from some place else. Water incoming from government source could be coming from any water storage plant that is then controlled in reservoir at different places

In our model for each domain a dedicated controller is used which is controlling the control action. These dedicated controllers report their corrective action to a master controller, which receives the data and transmit it using a wireless communication protocol to consumer’s smart device (Smartphone, Laptop etc.). From here Consumer can change the set points for corrective actions or take emergency actions if urgency occurs. So our system is fully automated with control of setpoint and emergency control to the consumer.

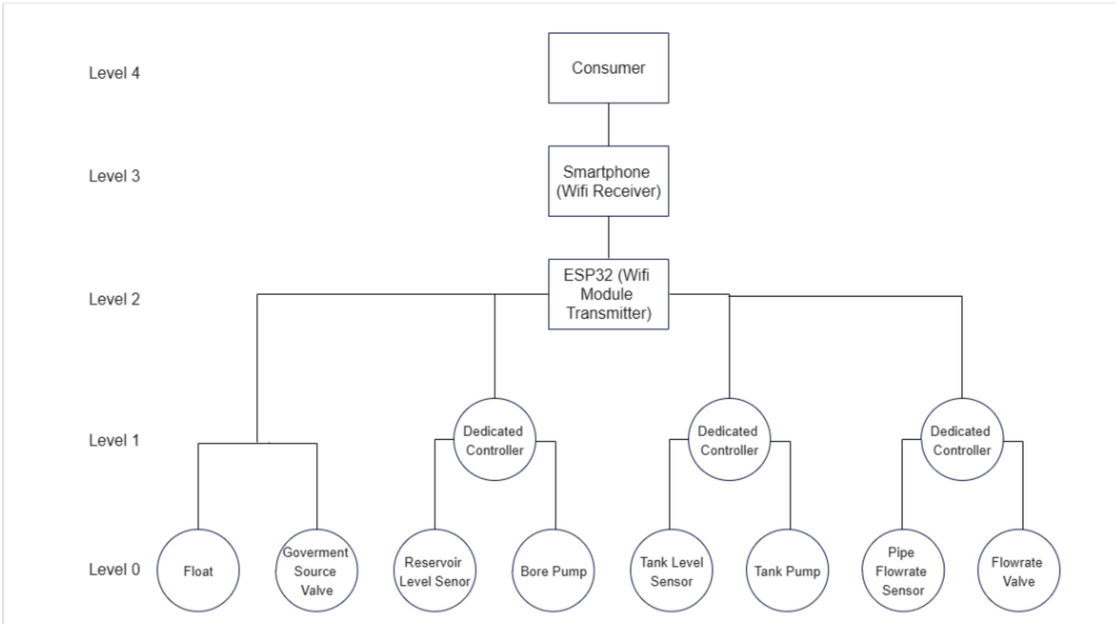

Figure 1.5

5. PROCESS FLOW DIAGRAMS (PFD)

Process flow diagrams consist of flow rate and compositions of streams, operating conditions, flows of utilities and major equipment symbols. Figure 1.6 shows the process flow diagram.

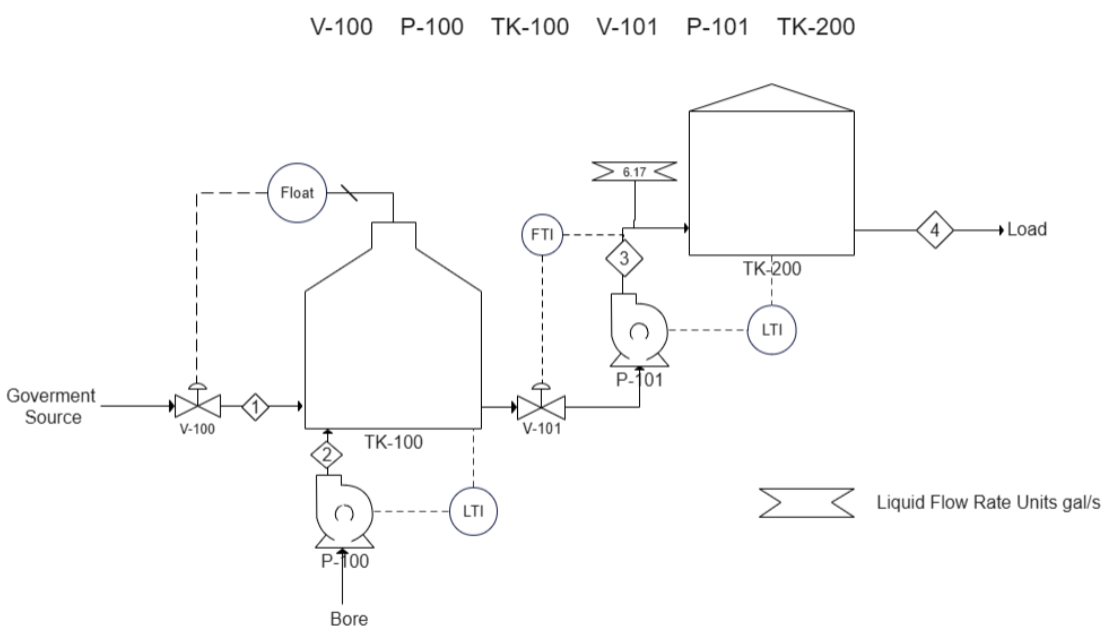

Figure 1.6

Summary table

Stream number	**1**	**2**	**3**	**4**
Flow rate (gallons/s)	-	-	6.17	-

PFD Legend

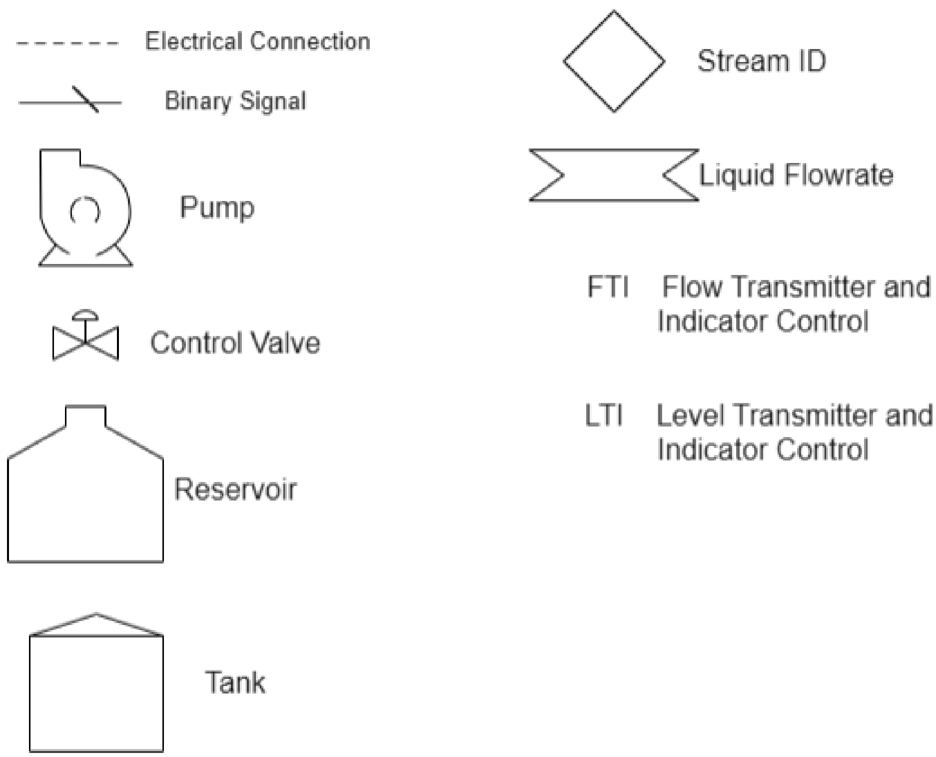

Figure 1.7

6. PIPING AND INSTRUMENTATION DIAGRAM (P&ID)

P&ID consist of every piece of equipment, all the details of piping and identification of instrumentations and utilities. Figure 1.8 and 1.9 shows the P&ID of reservoir and tank respectively.

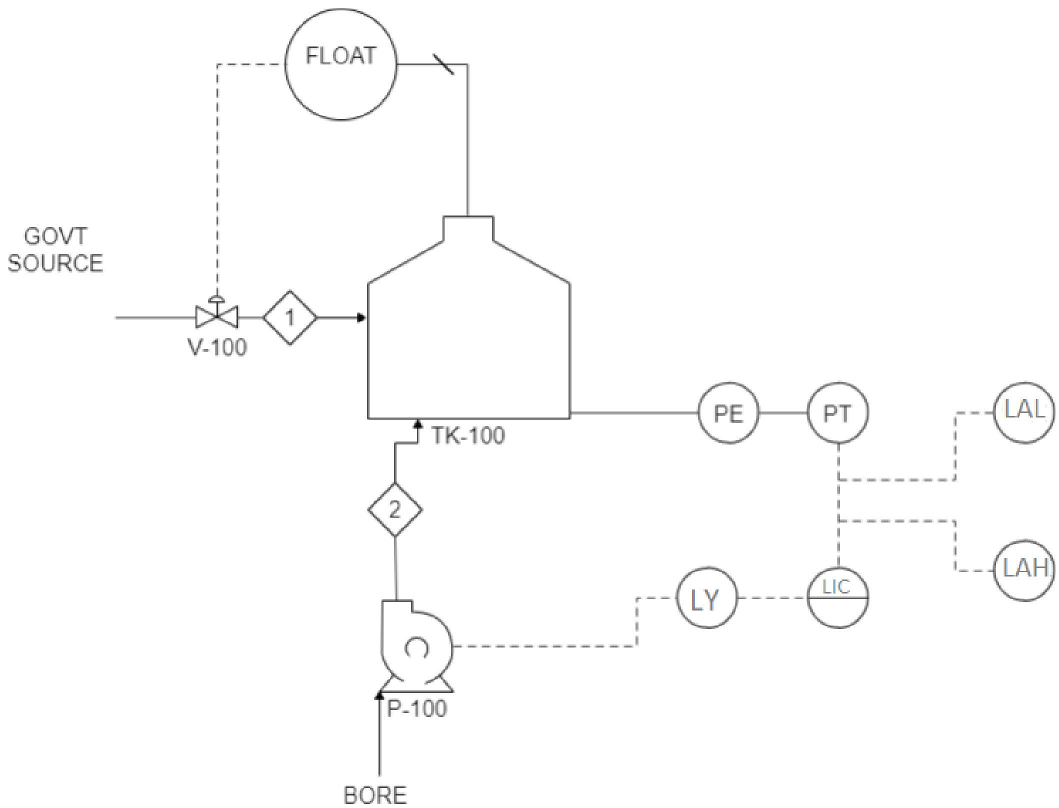

Figure 1.8 P&ID for reservoir

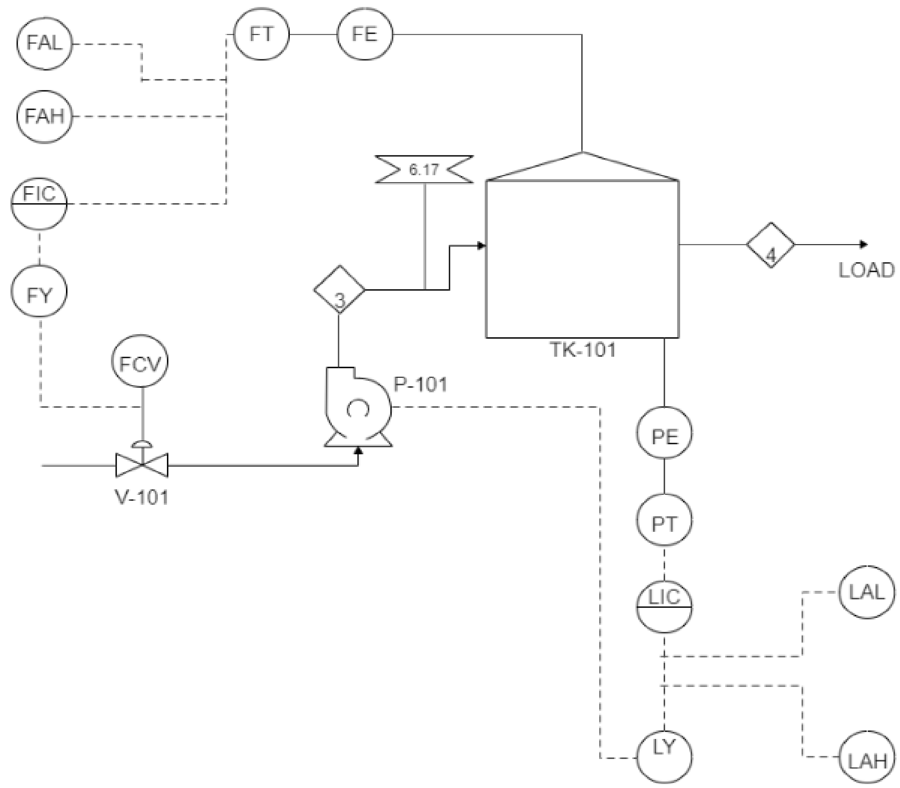

Figure 1.9 P&ID for tank

7. INDUSTRIAL EQUIPMENT AND INSTRUMENTATION

- Water Reservoir (10,000 gallons)
- Water Tank (3,333 Gallons)
- 4.5 inches Pipes
- Liquid Water Float
- Esp32 with Wi-Fi (Master Controller)
- Esp32 (Slave and Dedicated Controllers)
- WNK 4-20mA 0.5V-4.5V I2C Water pressure sensor (for level sensing) [3]
- Actuator Control valves
- 25 HP Pumps (for 480 Gallons per Minute Max) [4]
- Fotek KTM-50 Paddle Wheel Flow Meter with Transmitter [5]

8. CONCLUSIONS AND CONTRIBUTIONS

After solving this case, we are now able to design and automate comprehensive process control system such as in or household system. We acquired the knowledge of using different industrial equipment and instruments and steps necessary to perform required action.

201075	Calculations, Control System, Block Diagram, Equipment
201141	PFD, P&ID, Elements of Process Control System
201131	PFD, Control Block Diagram, Report Compilation

DIFFICULTIES FACED AND HOW WE OVERCAME THEM

- How to control F_2 and F_3. We have solved this issue by adding valves and pumps.
- Dimensions of pipe for water flow.
- Time taken 9 minutes in calculations to compensate any error encountered when tank is being filled with water under 10 minutes.

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