ME 421L

Automatic Controls Laboratory

CE117

Process Trainer

Lab 9: Flow control by Pump

Hamilton Institute

Based on original designs by Professor P.E. Wellstead

TQ Education and Training Ltd

REFERENCES: CE 117 Process Trainer Manual

1. Introduction: The CE117 Process Trainer

Refer to Lab 8 Manual

2. General Description

Refer to Lab 8 Manual

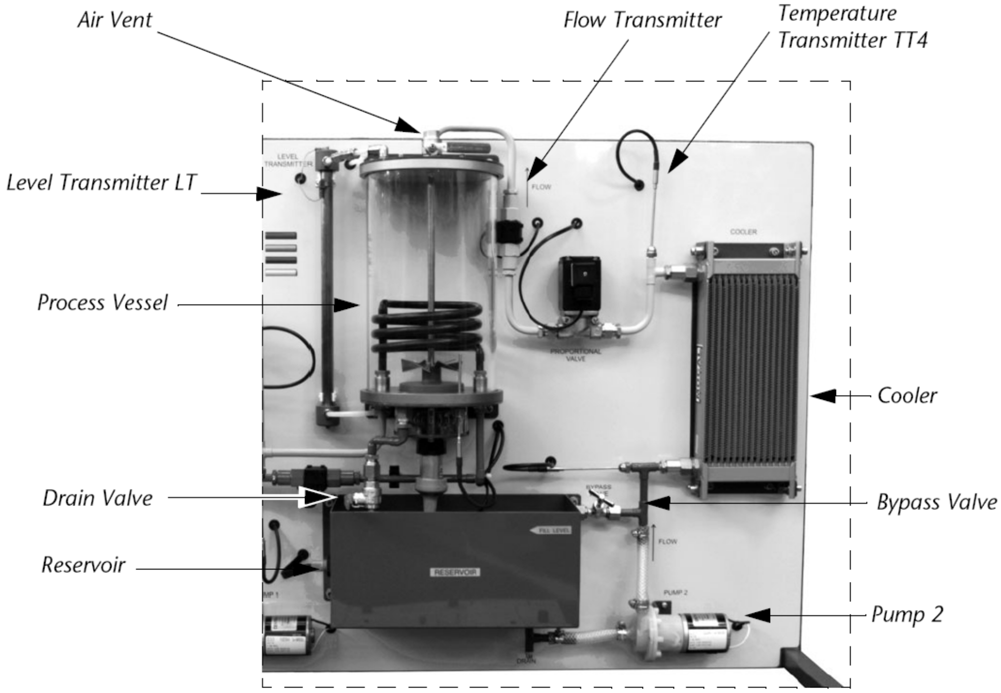

Figure 1 The Process/Cooler Flow Circuit

Table 1 provides the technical data for the hardware used on the CE117 Process Trainer.

Item		Analogue Signal	Conversion Details
PRT Temperature Transmitters (Platinum Resistance Thermometers)	**TT1 TT2 TT3 TT4 TT5**	0 - 10 V Output Linear	10°C per Volt 0 V = 0°C 10 V = 100°C
Flow Transmitters	**FT1 FT2**	0 - 10 V Output	1 L/min per Volt 0 V = No flow
Level Transmitter	**LT**	0 - 10 V Output Non Linear	0 V = Empty Vessel 10 V = Maximum Level
Pressure Transmitter	**PT**	0 - 10 V Output	100 mbar per Volt 0 V = 0 mbar (gauge)
Electric Heater		0 - 10 V Input	75 W per Volt 0 V = Heater Off 10 V = 750 W Maximum Power (Nominal)
Proportional Valve	**S**	0 - 10 V Input	0 V = Closed 10 V = Open
Pump 1 Pump 2		0 - 10 V Input	0 V = No Flow 10 V = Maximum Flow

Table 1 Analogue Signal Sockets on the Mimic Panel

3. System Dynamics

This section describes the dynamics of the Process Trainer. For more details, we recommend a popular book: "Process Dynamics and Control" by Seborg, Edgar and Mellichamp, (Wiley). Where possible, the symbols and notation used in the book are also used in this manual.

Notation

Symbol	Units	Description
C	J/kg K	Heat capacity of the fluid
A	m^2	Area
V	Litre	Volume of fluid in the process vessel
V_h	Litre	Volume of fluid in the heater tank
T	Celsius (°C)	Temperature of the fluid in the vessel
T_i	Celsius (°C)	Inflow temperature
T_h	Celsius (°C)	Temperature in the heater tank
T_o	Celsius (°C)	Outlet temperature from the heat exchanger
T_{ref}	Celsius (°C)	Reference temperature
P	Watts (W)	Heater input electrical power
w_i	kg/s	Inlet mass flow rate
w	kg/s	Outlet mass flow rate
Q	J/kg	Heat input to the process vessel from the heat exchanger
ρ	kg/m^3	Fluid density
q_i	L/min or m^3/s	Volumetric flow rate into the vessel
q	L/min or m^3/s	Volumetric flow rate out of the vessel
q_h	L/min or m^3/s	Flow rate through the heat exchanger.
K		A constant for the cooler
U_{fan}	V	Cooler fan speed input voltage

The Process Vessel

The heat exchanger in the process vessel supplies an input heat flow rate Q. The fluid feed to the system is at temperature T_i and mass flow rate w_i. The outflow temperature is T and mass flow rate w. The control variables are the fluid input flow rate, the outflow rate and the heat input to the heater. The general control objective is to control the temperature T and the volume of fluid (V) in the vessel. This type of system is the basis of many chemical process systems.

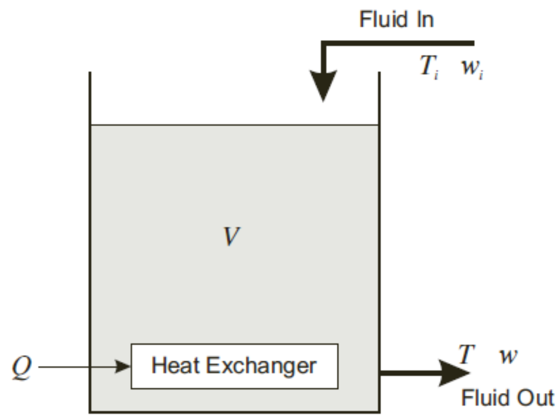

Figure 2 Process System Model

For the process vessel of volume V filled with water of density ρ, the mass of water in the vessel is given by $V\rho$. From Figure 2, the law of conservation of mass gives the mass balance:

$$(\text{Rate of mass accumulation}) = (\text{Rate of mass into the vessel}) - (\text{Rate of mass out of the vessel})$$

The mass balance equation is then

$$\frac{d(V\rho)}{dt} = w_i - w$$

Equation (1) can be rewritten as:

$$\frac{dV}{dt} = \frac{1}{\rho}(w_i - w) = q_i - q$$

The flow rate through the process loop is given by the relationship between the pump characteristics, the losses in the pipes and cooling systems, and the proportional valve. This is usually given by a set of curves which relate the pump input to the flow rate for various proportional valve positions.

4. Process Control Theory

The dynamics and control of process systems is an important subject. Properly configured and effectively tuned control systems have a major influence on the efficiency and safety of a process plant. In this section the main process control topics are reviewed and their application described in terms of the CE117 Process Trainer. The popular and widely used book “Process Dynamics and Control” by Seborg, Edgar and Mellichamp, (Wiley) is again recommend for more background and details.

Feedback Control of Flow

The control of flow rate through a pipeline occurs in process engineering when fluid, gas or a mixture of both is pumped through a pipeline or process network. The flow of fluid can be controlled in the Process Trainer in both the heater and process loops by:

- Control of pump speed (heater and process loop).
- Control of the proportional valve position (process loop only).
- A combination of the pump speed and valve position.
- Adjustment of the process loop by pass valve.

The control schemes for the pump speed and valve control are shown in Figure 3. Both methods of control are used in practical situations, depending upon the process system being considered. In some complex systems a mix of both schemes is used. For example, in a gas distribution network, pumps are used as the primary actuator. They move gas through the network from the source to the user. Local valves control the amount of gas taken from the network by users at various locations around the network.

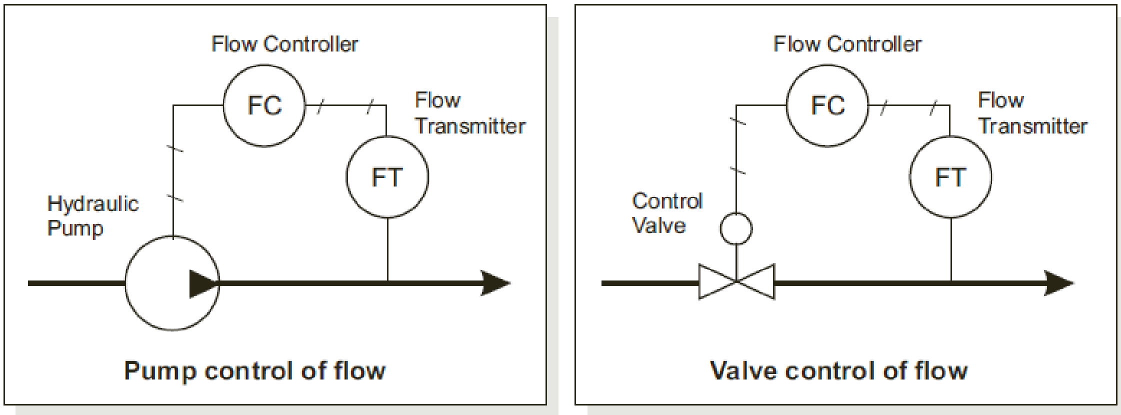

Figure 3 Two Methods of Flow Control

5. Experiments of Flow Control by Pump

Objectives

- To investigate the use of the pump speed for control of flow rate in the process loop.
- To demonstrate the effect of derivative action and the importance of the 'washout' filter.

Experiment 1: Flow Control with Proportional and Integral Action

1) Start the CE2000 software and load file '**exp3-1A.ict**'.
2) Close the loop bypass valve, fully open the process vessel drain valve and the air vent.
3) Connect the CE117 Mimic Panel as shown in Figure 4. Set Pump 2 switch to 'External'. Analogue signals will pass from the ADA section to Pump 2, the proportional valve (S) and from flow transmitter (FT2).

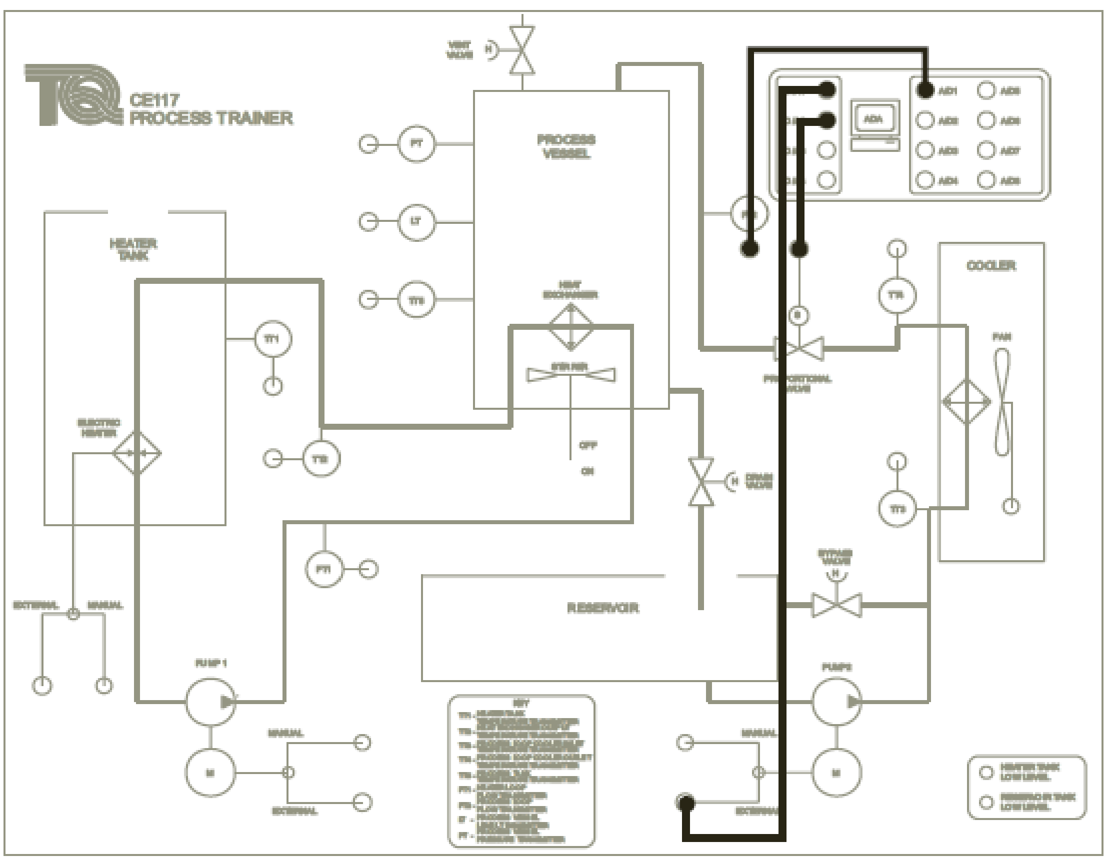

Figure 4 Connections for Experiment 1

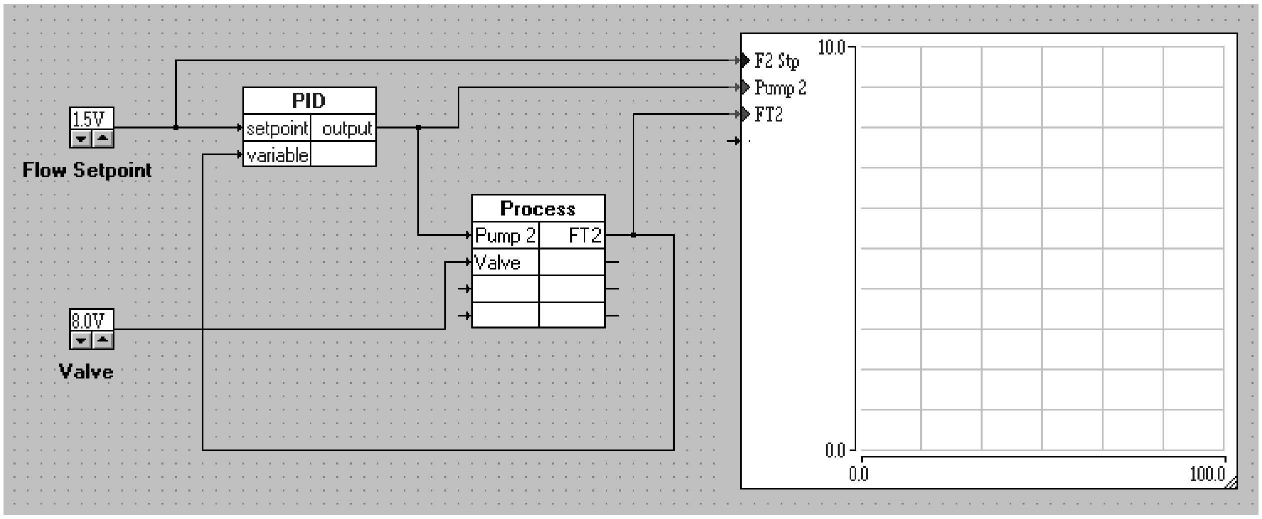

Figure 5 Screenshot of Experiment 1

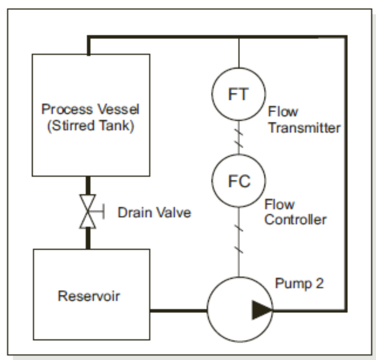

Figure 6 Schematic of Experiment 1

4) On the software, the block titled 'PID' is a three term controller that controls the pump voltage. You may adjust the controller's values of Proportional gain, Integral and Derivative. Set the PID controller to:

Proportional gain - 0.5
Integral - 0.5
Derivative - 0 (zero)

5) Run the software and use it to record the flow response. Adjust the Setpoint to 1 V and the valve voltage to 8 V and wait for the flow to stabilize.

NOTE *This experiment does not control level, so at setpoints above 2 V the reservoir can run low and switch off the pump. To avoid this, perform this part of the experiment as quickly as possible.*

6) Increase the flow setpoint in steps of 0.5 V up to a maximum of 3 V. At each step change, allow the flow to stabilize (should take less than 30 seconds). Adjust the flow setpoint back to 1 V and wait for the flow to stabilize (should take less than 30 seconds). You may use the software to record and create a chart of the results.
7) Increase the flow setpoint to 2 V and wait a few seconds for the flow to stabilize.
8) Part-open the process loop bypass valve to reduce the loop flow. Close the bypass valve, wait for the flow to stabilize. Reduce the valve voltage by 2 V to reduce the flow.
9) Draw a block diagram of the control system.

Questions

1. How well does the system respond to changes in setpoint?
2. How well does the system respond to disturbances?

Experiment 2 - Demonstration of Derivative Action

1) Start the CE2000 software and load file ‘**exp3-2A.ict**’.
2) Close the loop bypass valve, fully open the process vessel drain valve and the air vent.
3) Connect the CE117 Mimic Panel as shown in Figure 7. Set Pump 2 switch to ‘External’. Analogue signals will pass from the ADA section to Pump 2, the proportional valve (S) and from flow transmitter (FT2).

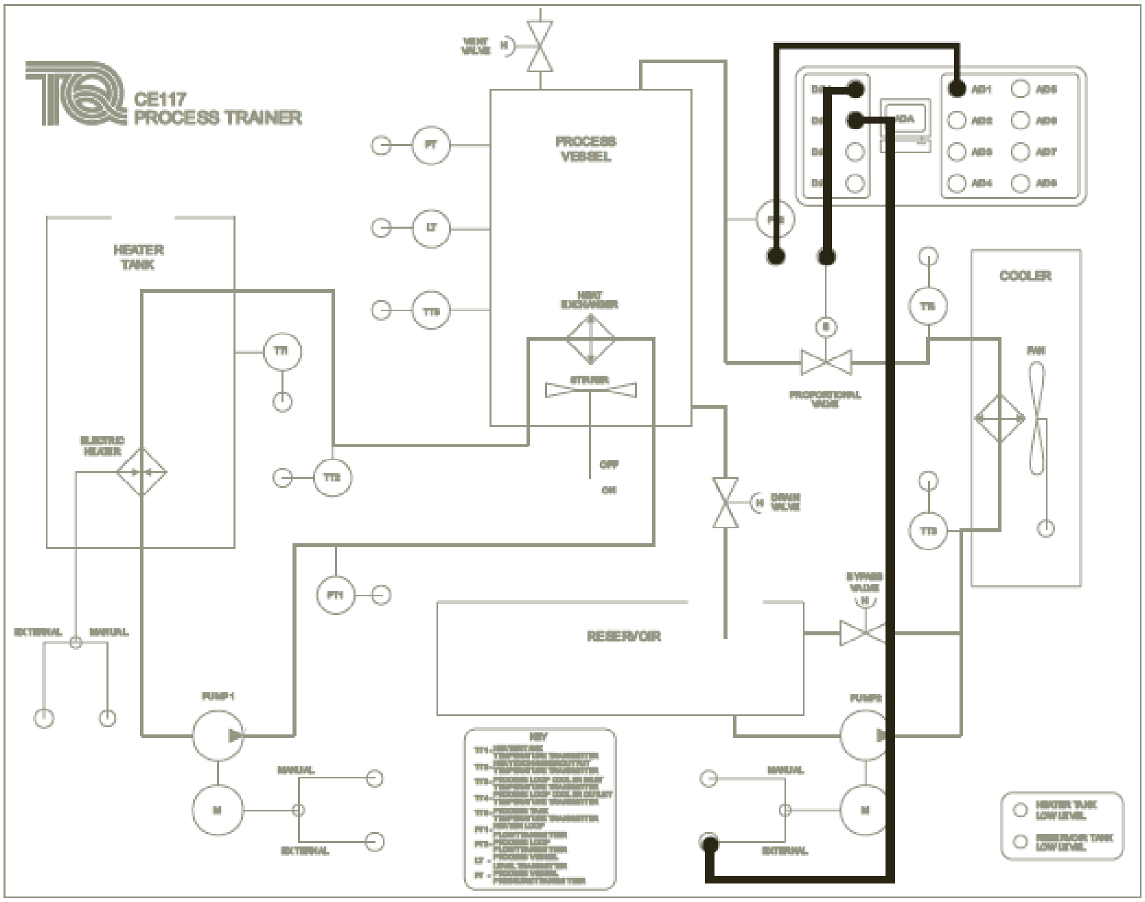

Figure 7 Connections for Experiment 3 Procedure 2

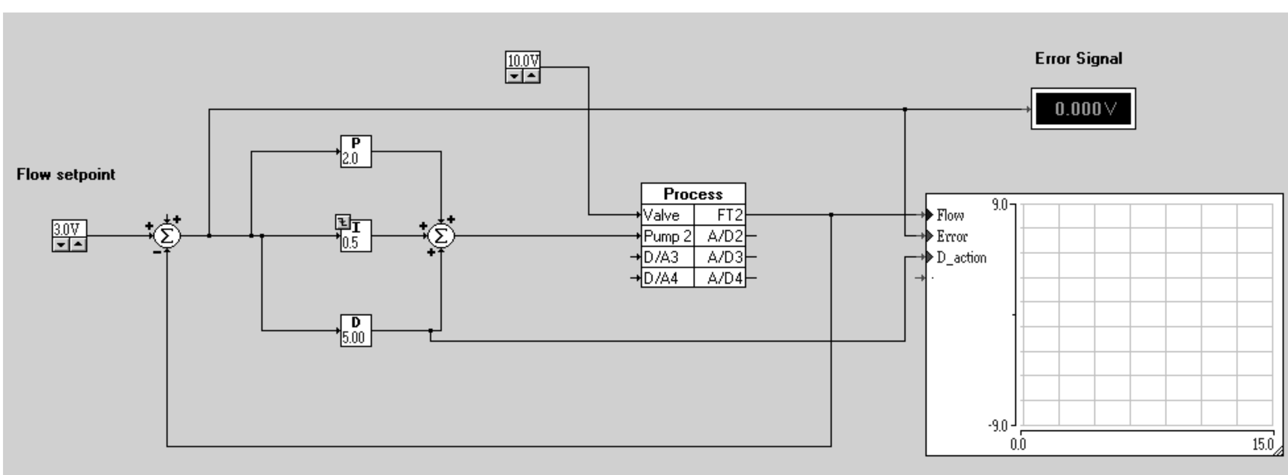

Figure 8 Screenshot of Experiment 3 Procedure 2

4) On the software, a three term controller is made from three individual (P, I and D) blocks that control the pump voltage. Set the blocks to:

Proportional gain - 2
Integral - 0.5
Derivative - 0 (zero)

5) Run the software and use it to record the flow response, the error and the derivative action (D_action). Adjust the Setpoint to 2 V and the valve voltage to 10 V (fully open) and wait for the flow to stabilize.
6) Increase the flow setpoint by 1 V. Note that the output from the derivative block (D_action) does not change. Decrease the setpoint by 1 V and again note that there is no output from the D block.
7) Stop the software and change the D block gain to 5 and its Washout gain to 5. Make sure that the Washout 'Enabled' check box is ticked. Run the software and allow it to stabilize.
8) Increase the flow setpoint by 1 V. Note the output from the derivative block (D_action). Decrease the setpoint by 1 V and again note the D block output (D_action).
9) Stop the software and make sure that the Washout 'Enabled' check box is ***not*** ticked. Run the software and allow it to stabilize. Repeat step 8.
10) While the software runs, enable and disable the washout filter.

Questions

3. What do you notice about the output of the D block and its effect on the pump speed?
4. What do you notice about the effect of the Washout Filter?

Support your answers with the proper charts/screenshots for different steps you made.