Experiment 3: Temperature Control of Heat Exchanger
(TBC 1/21/2012, 2/11/2017, 1/28/2019, 1/10/2020)

Main Task: To implement a feedback temperature control of the hot water exiting a heat exchanger.

Station No. _____

Team Members: 1) _____

2) _____

3) _____

Tasks

a) Setup (Labview and USB6008/6009 connections) _____
b) Steady state value : $T_{ss} =$ $°C$
c) Heating and cooling profile (Excel plot) _____

I. Feedback Control Setup

A. Hardware

The signal u is a voltage ranging from 0 to 5 volts, whose value will be determined using the proportional control law given by

$$u = u_0 + K_c(T_{set} - T_m)$$

where u_0 is the bias value based on the nominal steady state performance, K_c is the proportional gain, T_{set} is the set point temperature and T_m is the measured value of the temperature of the heated water. The control scheme is shown in the block signal diagram shown in Figure 1 below. In the figure, the actuator includes the transducer and the control valve.
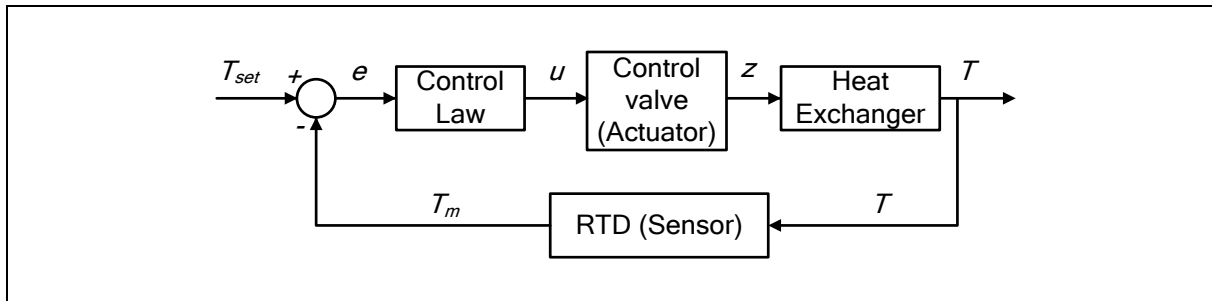

Figure 1. Feedback loop.

The NI USB6008/6009 supplies 5v from the digital side. Voltage signal from the RTD are input to the USB device via the AI0 port, while voltage signal from the laptop will be sent to transducer via the AO0 port.

Note: connect the positive (+) port of the transducer to AO0 port of USB6008 and connect the negative (-) port of the transducer to the GND port. of USB6008.

B. Labview Program (Note: you need to connect the DAQ device and already have the hardware driver installed before you procede.)
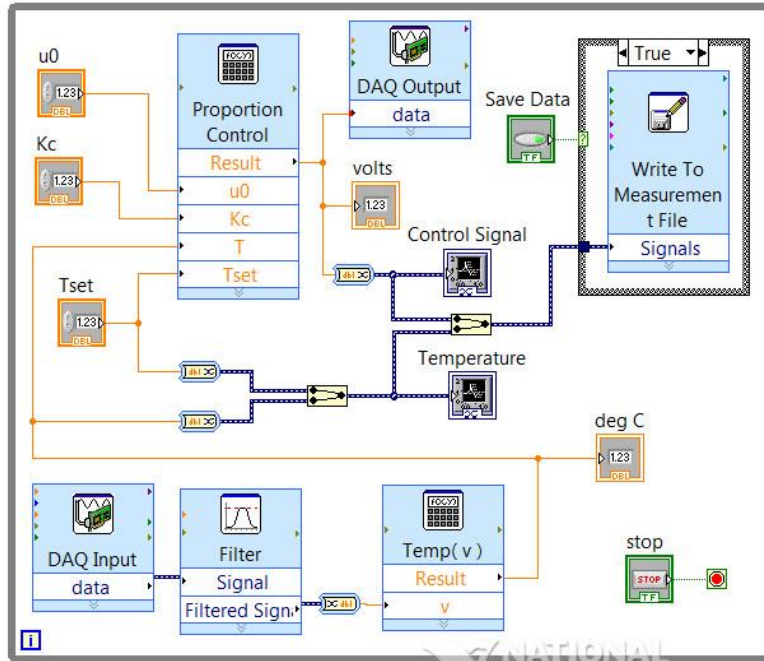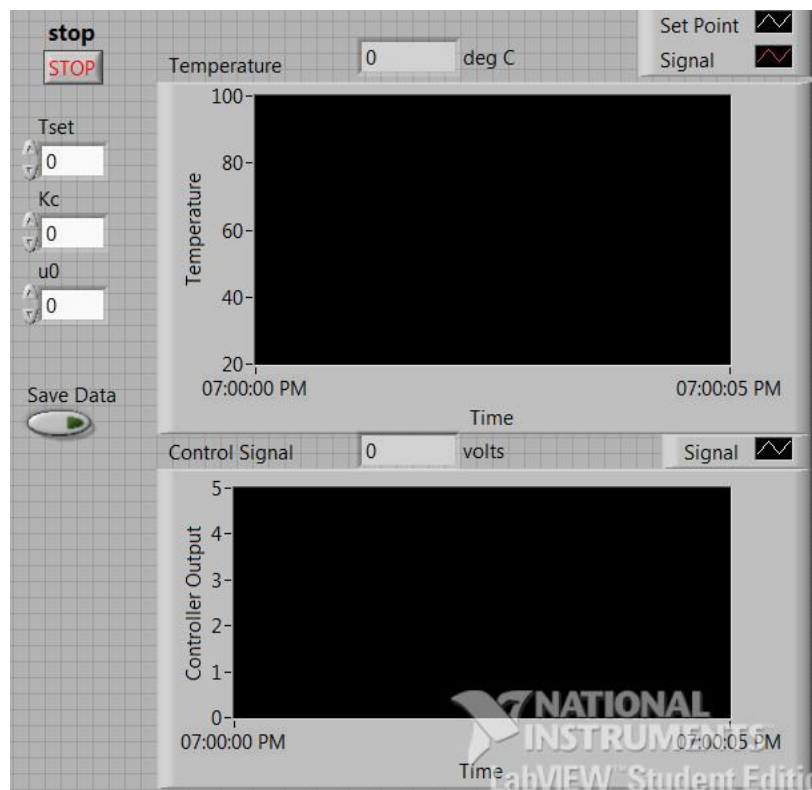
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Figure 2. Labview block diagram.

Figure 3. Labview front panel.

1. Start with same set-up and blocks as in Lab 2 including the RTD blocks.
2. Create the control law blocks:
    a. Import **[Express]→[Arithmetic and Comparison]→[Formula]** block, then type in the following formula:

       ```
       max(0,min(5,u0+Kc*(Tset-T)))
       ```

       (**Note**: this is to keep the value of u within 0 and 5 volts, otherwise an error will occur during the run if u is allowed to have negative or values greater than 5)
    b. Right-click on each of the inputs, then select [Create]→[Control].
    c. Import **[Express]→[Output]→[DAQ Assist]** block. Select **[Generate Signals]→[Analog output]→[Voltage]**. Select port **AO0**. Then set max to 5 and min to 0.

       (Leave the setting on [**On demand**])
    d. Connect wires as shown in Figure 2. You will need to including a merge signals block: **[Express]→[Signal Manipulation]→[Merge Signals]**
3. Create the "write to measurement" blocks (refer to steps in Lab 1).

II.   Heat Exchanger Startup

(based on procedure for heat transfer coefficient experiment found in CM3215 developed by F. Morrison, revised for CM3310 by T. Co)

CAUTION: Always wear insulated gloves when adjusting the steam valve, when touching uninsulated piping or when handling condensate. The equipment may be hot at the beginning of lab.

If the TA has not done it yet, connect the transducer to the compressed air supply and to the steam valve. (see Figure 4.)
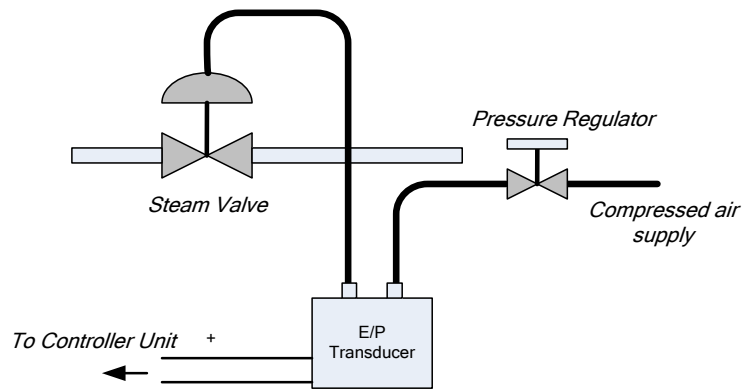

Figure 4. Connecting the transducer to the air supply and steam valve.

Begin water flow in the loop as follows:
1. Start water flow through the ½" pipe as follows. Make sure that tank T-02 is empty and clean. Close the drain valve (DV-2).
2. Open water valve WV-10 and fill T-02 with water. Once the tank is filled, the water control float valve will shut-off water flow. The water control float valve keeps water level constant at a set point.
3. Make sure valves WV-1, WV-2, and WV-3 as well as the needle valve WV-5 are all closed.
4. Turn on pump P-01.
   a) Turn power on
      - Make sure display is on "d001"
      - After a few seconds "0.0" should appear and "Hz" led is lit
   b) Use "up" and "down" arrow to make sure speed is set at 25.0 Hz
   c) Push [Green] button to start pump
5. Direct the water through the ½" pipe by opening valve WV-1. Turn three-way valve WV-4 knob to direct the water flow through rotameter FI-01. Make sure that valves WV-6 and WV-7 are closed. Adjust three-way valve WV-8 to direct water to the heat exchanger E-01. Turn three-way valve WV-9 knob to direct water to T-02.
6. Fix the water flow rate to 15% on FI-01 by using needle valve WV-5.

Begin flow of steam through the outer jacket of the heat exchanger as follows:
7. Position three-way valve SV-3 to direct flow through the steam trap 2.
8. Open the main steam valve SV-1.

Drain condensate from the line as follows:
9. Check with the TA to see if this step has been done; if not, using insulated gloves, position the black rubber drain hose located downstream of SV-2 in a Styrofoam bucket. One team member should stabilize the bucket and hose.
10. Using insulated gloves, open SV-2 slowly to drain all of the line condensate into the bucket. Close SV-2 when steam begins to come out of the hose. Dispose of the condensate in a floor drain – do not use the sink drain. Clean up any water spills with paper towels.
11. Return the rubber hose to common drain.

Start steam flow:

12. Open DV-1. Turn three-way valve WV-9 knob to direct water to T-01. Verify that the pump is on and that water is circulating through the inside of the heat exchanger. Do not recirculate water back to tank T-02.

13. Open main air valve AV-1 and set the control valve FV-06 to 18 psig.

III. Control Experiment

1. Set $u_0 = 4.0\ volts$ and $K_c = 0$ (this sets the control law to be a manual mode) and note what the steady state temperature is, T_{ss1}.
2. After steady state has been achieved, start collecting data to a file by clicking the "Start data" button.
3. Change the setpoint to $T_{set} = T_{ss1} + 5$, then change the proportional gain to $K_c = 0.5$.
4. After a new steady state has been achieved, change the set point to $T_{set} = T_{ss1} - 10$.
5. Wait until the new steady state, stop the program.
6. Plot your data on Excel.

IV.   Heat Exchanger ShutdownProcedure

(based on procedure for heat transfer coefficient experiment found in CM3215 developed by F. Morrison, revised for CM3310 by T. Co)

1. Set the air pressure regulator to 0 psig using the pressure regulator.
2. Close the main air valve AV-1.
3. Close main steam valve SV-1.
4. Return all drain hoses to the common drain.
5. Allow the cold water to circulate through the loop to cool the heat exchanger for at least 3 minutes. Stop when the piping at the cold-water exit of the heat exchanger is cool to the touch.
6. Close valves WV-1 and needle valve WV-5.
7. Turn off pump P-01.
    a. Push [RED] button
    b. Switch power off
8. Close main water valve WV-10.
9. Position three-way valve WV-9 to direct flow to Tank T-02.
10. Drain all tanks.
11. Dry off any wet surfaces with paper towels. Turn off all the electronic devices and properly store them.
12. (If you are in the last session of the day, detach the transducer from the compressed air line and the steam valve then reconnect air line directly to steam valve).