Heat Exchanger Experiment

Table of Contents

Contents

P&ID For Heat Exchanger **4**

Safe Operation Conditions: **7**

Checklist before Startup operation **8**

Part I. Shell and Tube Heat Exchanger (Hair-Pin) **9**

Section A: Start up Procedure 9

Section B: DELTA-V 12

Section C: Data Collection for Tube and Shell 16

Section D: Shutdown procedure 18

Part II. Shell and Tube Heat Exchanger (Single Tube Pass) **19**

Section A: Start up Procedure 19

Section B: Delta-V 20

Section C: Data Collection for Hair Pin and Plate HX 21

Section D: Shutdown procedure 22

Part III. Plate Heat Exchanger **23**

Checklist for Shut Down **24**

Troubleshooting **24**

Overall Experimental Setup

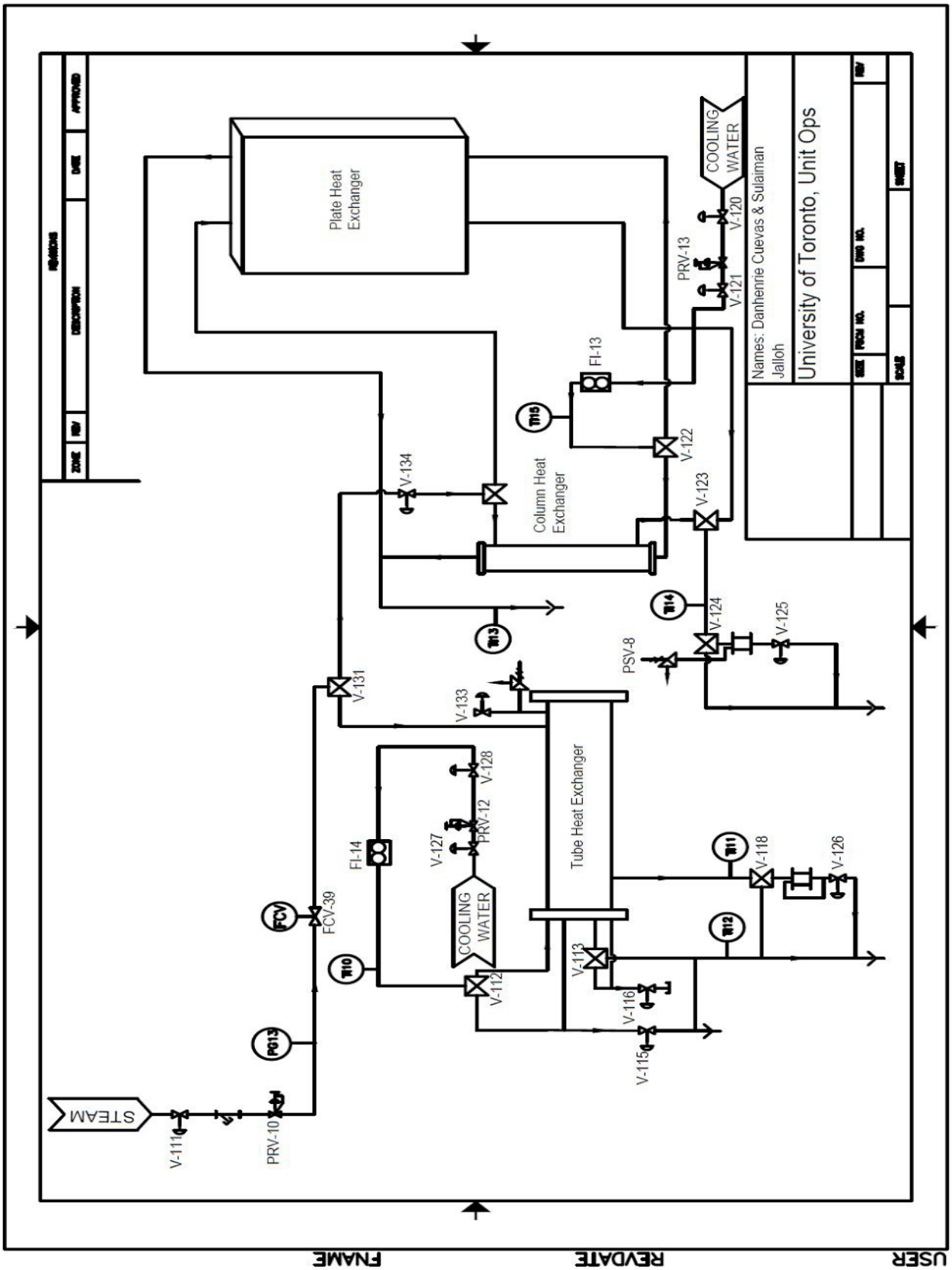
This Heat Exchanger system consist of plate, shell and tube, and hair pin units, pressure gauges, valves, flowmeters, condensate drains, transmitter, automated FCV, pressure relief valve and temperature dials.

Figure 1. Tube and Shell Exchanger (Hair-Pin)

Figure 2. S/T Heat Exchanger (single tube pass)

Figure 3. Plate Heat Exchanger

P&ID For Heat Exchanger



Instrument Index

Table 1: Instrument Index

Tag	Instrument
V111	Valve for steam
V112	Three Way Valve
V113	Three Way Valve
V115	Valve
V116	Valve
V118	Three Way Valve
V120	Valve for Cooling Water
V121	Valve for Cooling Water
V122	Three Way Valve
V123	Three Way Valve
V124	Three Way Valve
V125	Valve
V126	Valve
V127	Valve
V128	Valve
V129	Valve for Product Tank 1
V130	Valve for Product Tank 2
V131	Three Way Valve
V133	Valve
V134	Valve
F1-13	Variable Area Flow Meter

FI-14	Variable Area Flow Meter
PRV-10	Pressure Reducing Valve
PRV-12	Pressure Reducing Valve
PRV-13	Pressure Reducing Valve
FCV-39	Flow Control Valve
TI10	Temperature Indicator
TI11	Temperature Element
TI12	Temperature Element
TI13	Temperature Element
TI14	Temperature Element
PG13	Pressure Gauge

Safe Operation Conditions:

- Never allow the water flowrate temperature of out to exceed 49C. Low water flow rate and high steam pressure can result in vaporization of the water in the tube side. This can result in equipment damage and personal injury.
- Do not exceed 15 psig when adjusting the pressure reducing valve PRV-10
- Do not exceed 15 psig of PG13 when adjusting the valve V-111 during the introduction of steam into the system
- Always use insulated gloves when operating on the steamline
- Leave cold water on for the heat exchanger after shutdown to cool down the system
- Look out for leaks, unusual sounds, and overheating and report to the T.A in case of an Emergency

Checklist before Startup operation

- ❑ Steam valves V-111, PRV-10 are closed
- ❑ Cold water valves V-121 and V-128 are closed
- ❑ Steam bypass valves V130, V132 and V-134 are closed
- ❑ Delta-V is displaying main menu
- ❑ Digital readout of FCV-39 is at 0psi
- ❑ The pressure gauge (PG 13) reading on the steam line is registering zero
- ❑ FI-13, FI-14 show 0% flow
- ❑ Check both condensate traps and ensure 0% liquid level
    - ❑ If not, open valve V-125 or V-126 for drainage

Part I. Tube and Shell Heat Exchanger (Hair-Pin)

Section A: Start up Procedure

1. Adjust three-way valves V-112 and V-113 to allow cooling water (CW) to flow through both pairs of tubes of the Tube and Shell HX (See *Figure 22)*

2. Ensure both drain valves V-115 and V-116 are in the closed position (See *Figure 23)*

Figure 5. Cooling water control valves V-112 and V-113

Figure 6. Cooling water drain valves V-115 and V-116

3. Open CW valve V-128 and use PRV-12 to adjust flow to 70% as seen in FI-14

4. Before adjusting steam valves, ensure PG-13 reads 0psig

5. Ensure valve V-131 is in the correct orientation to allow steam into tube and shell HX
    a. This valve is very difficult to turn, use a stool when adjusting for better leverage

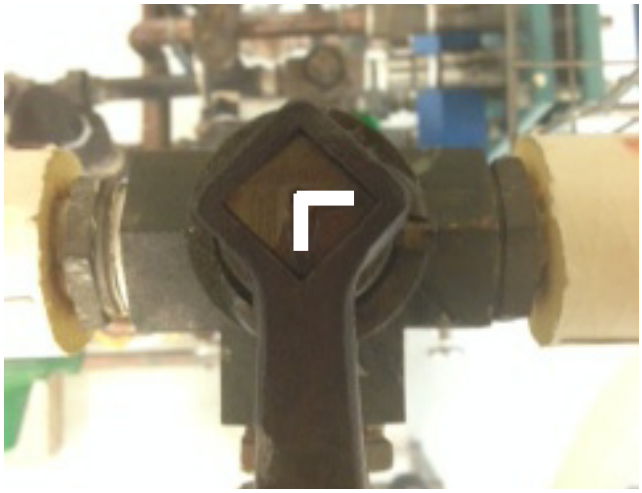


Figure 7. Three-way valves V-131 showing correct steam pathway

6. Ensure valve V-126 is open and verify that there is no condensate in the trap

7. Adjust "three-way valve" V-118 to ensure condensate will pass through trap

Figure 8. "Three-way valve" V-118 for condensate return

8. Verify PG-14 reads 0psig before opening bypass valve V-130

9. Verify steam pathway by following the piping. Ask a TA to double check the valves if there is any chance you are not sure.

10. Turn on steam **SLOWLY** using valve V-111. **Caution: Use insulated gloves.**

11. Open steam pressure reducing valve PRV-10 **VERY SLOWLY.** If any knocking noise is heard inside the pipes, STOP turning the valve, you may even want to reduce pressure by turning the valve back a half turn counter-clockwise. This knocking sound is STEAM HAMMERING which can destroy valves and pipes.
    Caution: Use insulated gloves.

12. Use PRV-10 to VERY SLOWLY adjust steam pressure on PG-13.
    Do not exceed 5psig (PG-13) while flushing out condensate

Figure 9. Steam Control Valve V-111

Figure 10. Pressure Reducing Steam Valve PRV-10

13. While condensate is flushing, proceed to start up Delta-V

Section B: DELTA-V

1. Click on “CHE 305 Heat Exchanger(s)” at the main screen of the computer.

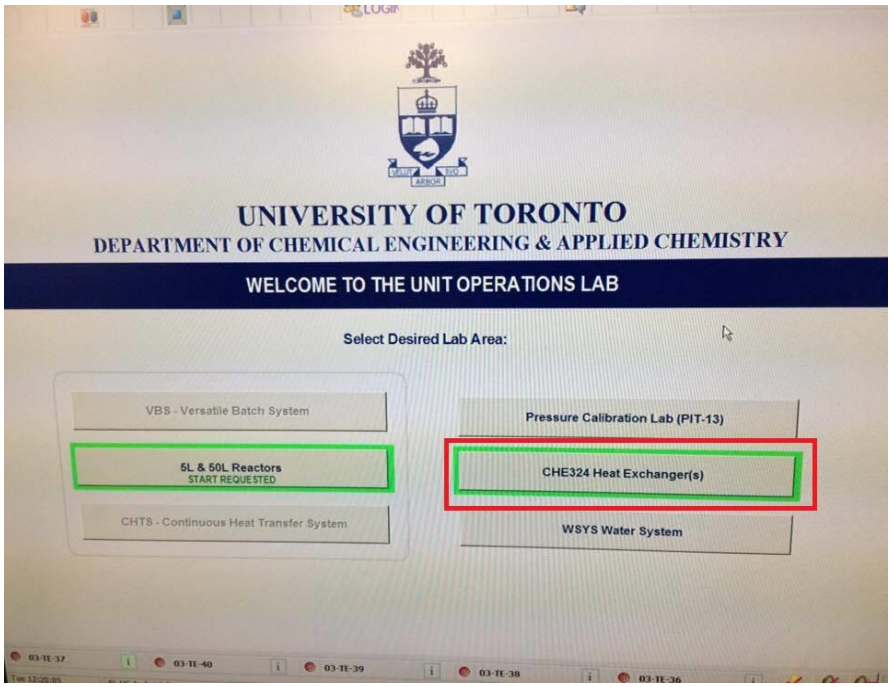


Figure 11. Main Screen of the computer for the DELTA-V system

2. On the right hand side, there steps for running the heat exchanger. First click “Start” then proceed to “Name & Mode Entry”.

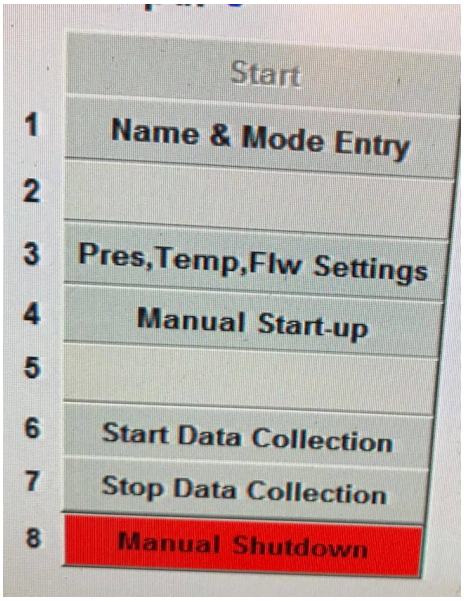


Figure 12. Steps for operations of the DELTA-V

3. Type in Date, TA name, Course code, student name and email then click “OK”.

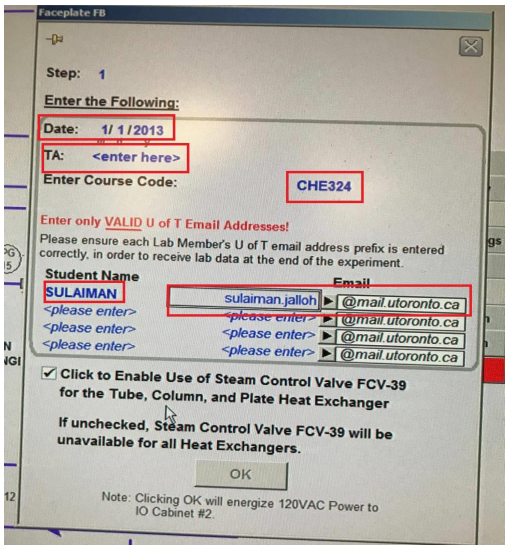


Figure 13. Entries for details of operator

4. Click on “Pres, Temp, Flw Settings” and the Faceplate will appear. Then click on “OK”.

5. Click on “Manual Start-up” and check off steps for **one heat exchanger** investigated.
    a. This step is to verify you have properly followed the Part A HX setup

6. Once you have checked off Step 12 (or 13 for Hair Pin or Plate HX), you can initiate flow control by going back to the DeltaV P&ID display (“Go back” button) and selecting FCV-39

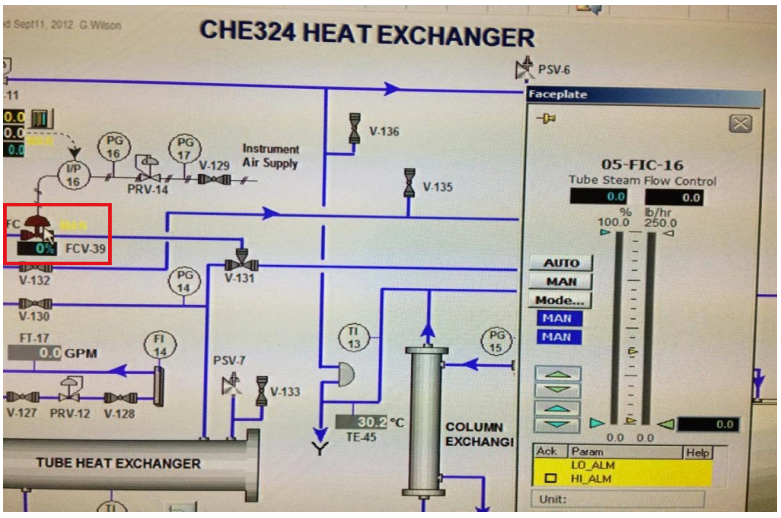


Figure 14. Delta-V system

a. Increase flow with FCV-39 by increments no greater than 20% at a time by clicking the box (See below) and inputting a value. Do not go past 60% at this point in time.

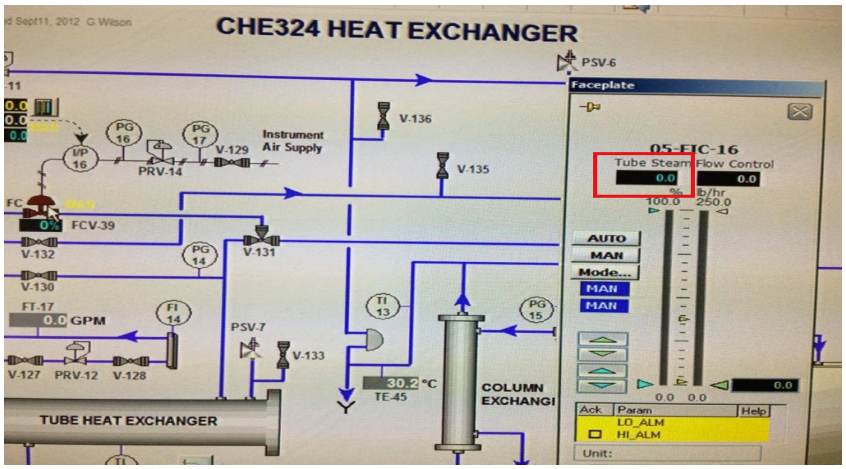


Figure 15. FIC-16 Faceplate to open FCV-39

b. Once FCV-39 is opened, close bypass valve V-130 (If using Hair Pin or Plate HX, close V-132). All steam flow through system is now controlled using FCV-39 on Delta-V, don't forget to complete the checklist

Figure 16. Valve FCV-39 used to activate steam flow

7. Click on "Start Collection". If you cannot click this button, you have not finished the checklist

8. Once the FCV-39 is open and bypass is closed, re-adjust the pressure using the PRV-10 and examine the pressure gauge PG-13. You many now use PRV-10 to increase steam pressure. **Pressure should not exceed 15psig. Note. If pressure does not change by opening the PRV valve , you can manipulate the pressure by V-111**

Figure 17. Steam Pressure gauge PG-13

9. You can now adjust the flow through FCV-39 and examine the effect it has on the temperature of the condensate and cooling water flowing out of the HX. This graph can be seen by clicking the appropriate button for the HX being examined (See below)

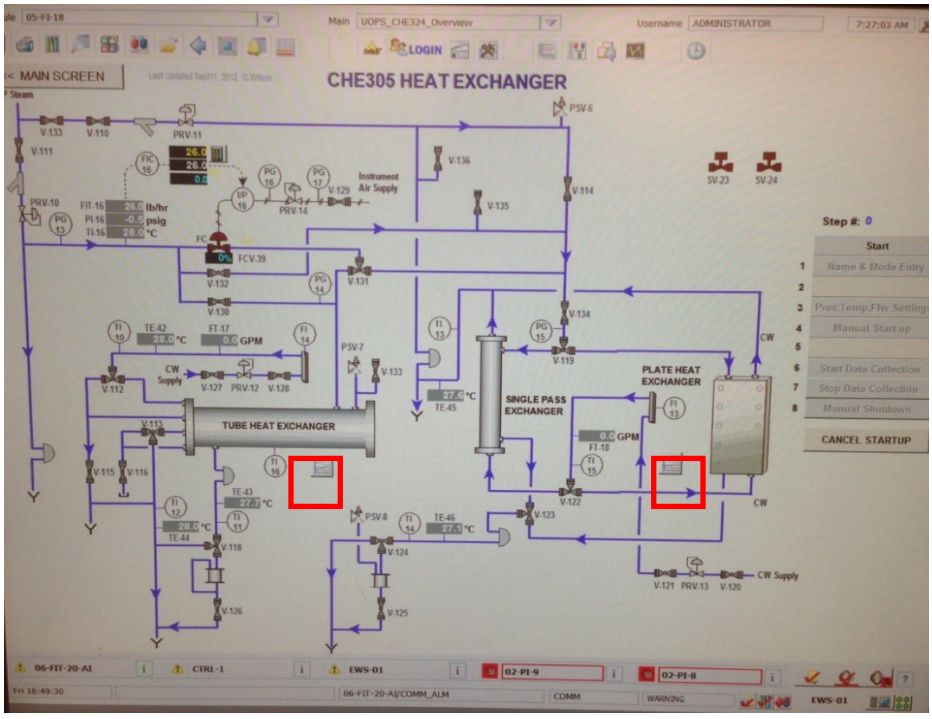


Figure 18. The left button opens the Tube HX graph, the right opens the Hair Pin and Plate HX graph.

Section C: Data Collection for Tube and Shell

1. The following recordings are taken from the physical gauges on the HX once the system has reached steady state. Observe associated graph to determine steady state.

2. Record the inlet temperature of cold water stream from TI-10.

3. Record the outlet temperature of cold water from TI-12.

4. Record the outlet temperature of the steam line from TI-11.

5. Measure and record the steam pressure using PG-13 (Figure 21)

6. Measure and record from indicated instruments shown in Figure 26 to compare readings from apparatus and Delta V software.

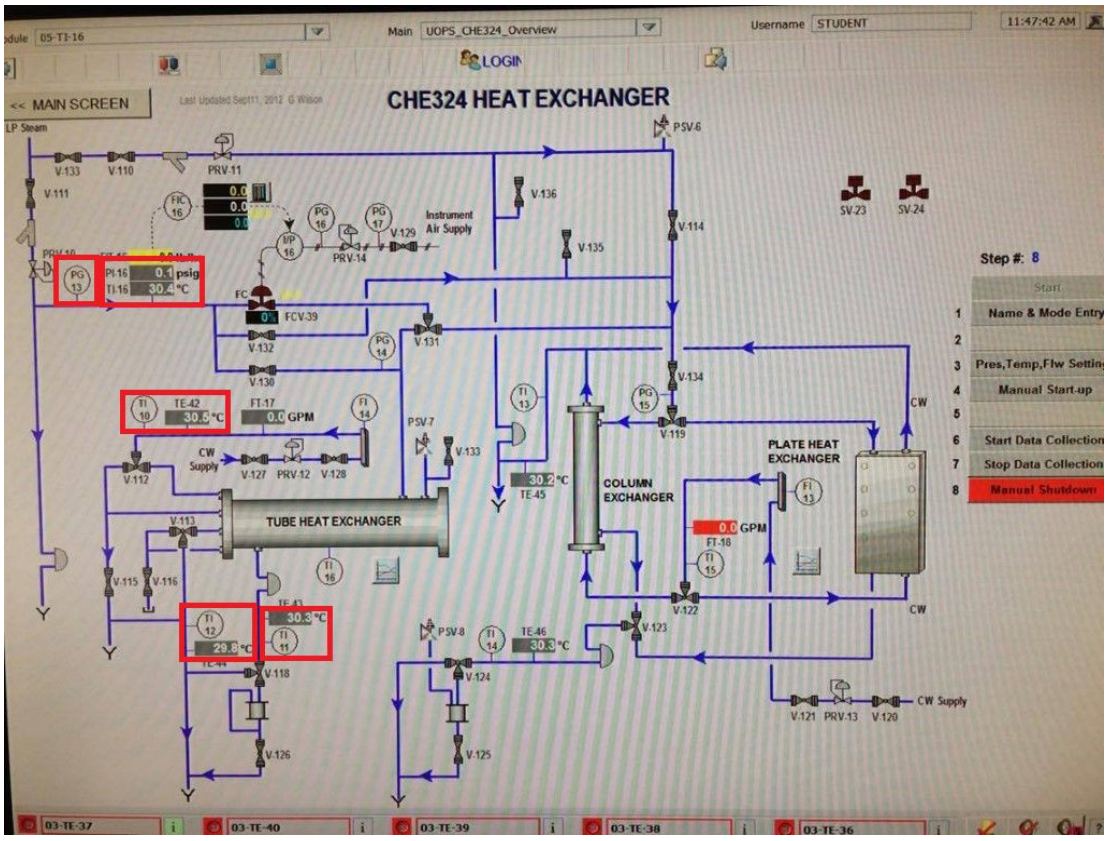


Figure 19. Location of temperature indicators for tube and shell heat exchanger.

Table 2. Instrument and measurement of Delta V software.

Instrument	Measure
PG16	Inlet Steam Pressure
TI-16	Inlet Steam Temperature
TE-42	Inlet Cold Water Temperature
TE-43	Outlet Steam Temperature
TE-44	Outlet Cold Water Temperature

7. Measure the condensate flow rate by recording the time it takes to reach the mark on the glass (desired level)
    a. This is done by closing valve V-126 to allow condensate to build up in trap
    b. The volume up to the mark is 300mL

Figure 20. Tube & Shell condensate trap

Section D: Shutdown procedure

1. Before proceeding to the next HX, you **must shut down** the steam so the valves can be adjusted safely

2. Click “Stop Data Collection”

3. Close V-111 and back off PRV-10 **Use insulated safety gloves.**

4. Set the valve position of FCV-39 using the delta V program to 0%
    a. Decrease setting by maximum 20% intervals

5. Click “Manual Shutdown and verify steps shown on the checklist and click “OK” to shutdown program
    a. Exit program to go back to the main screen.

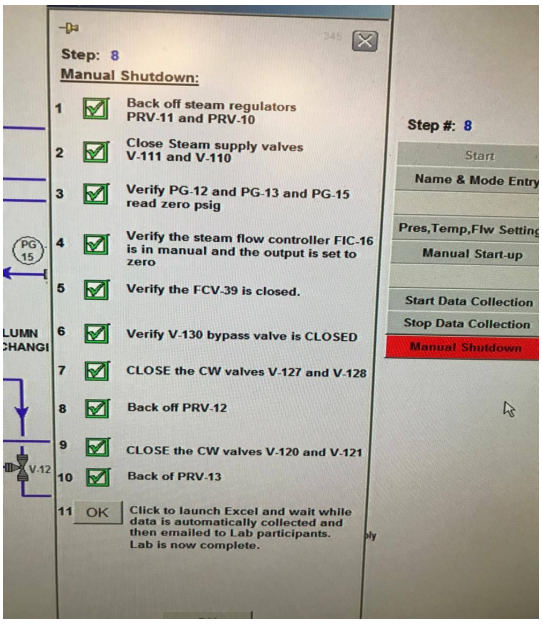


Figure 21. Manual shutdown protocol

6. For Tube and Shell HX, reduce valve V-128 to 15% flow indicated by FI-14

7. For Hair Pin and Plate HX, reduce valve V-121 to 15% flow indicated from FI-13

8. Ensure liquid is drained in condensate trap

Part II. Shell and Tube Heat Exchanger (Single Tube Pass)

Section A: Start up Procedure

1. Position three-way valve V-122 to allow cold water to flow through the Hair Pin HX (*Figure 5*)

2. Slowly open V-121 to introduce cooling water into the system
   - Adjust flow seen in FI-13 to 80%

3. Configure valve V-131 for the desired steam pathway for Hair Pin HX (*Figure 6*)
   - This valve is very difficult to turn, use a stool when adjusting for better leverage

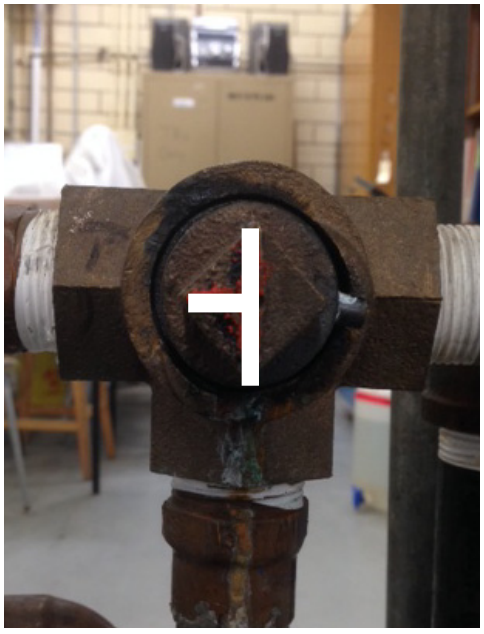


Figure 22. Three-way valve V-122 for cooling water flow

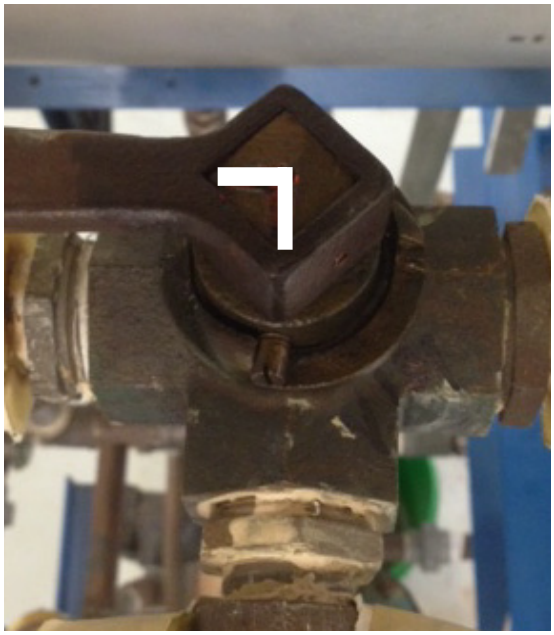


Figure 23. Three-way valves V-131 showing correct steam pathway

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4. Configure three-way valve V-119 to allow steam into Hair Pin HX and three-way valve V-123 to allow steam out of Hair Pin HX. (Note, V-123 only turns counter-clockwise)

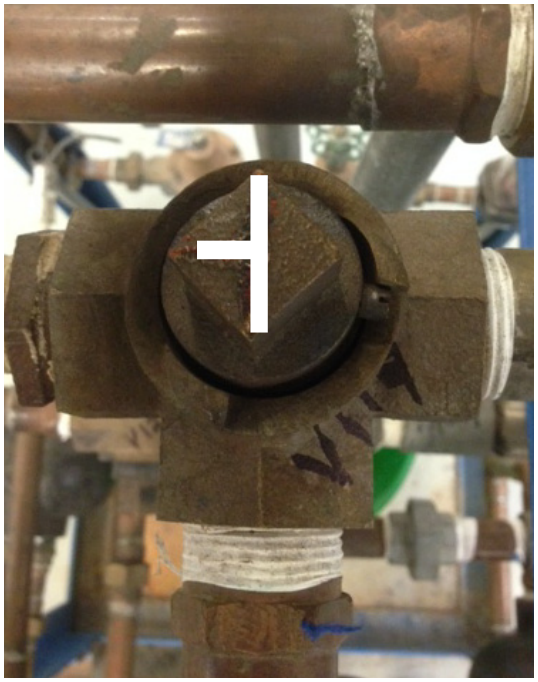

Figure 24. Three-way valve V-119 introducing steam to Hair Pin HX

Figure 25. Three-way valve V-123 allowing steam out of Hair Pin HX

5. Configure three-way valve V-124 to allow condensate to pass through trap and ensure valve V-125 is open.

Figure 26. Three-way valve V-124 to condensate trap

6. Open bypass valve V-132 to prepare system for condensate flush

7. Follow Part I A steps 10-13 to introduce steam into the system

Section B: Delta-V

- Follow Part I B for Delta-V startup

Section C: Data Collection for Hair Pin and Plate HX

1. The following recordings are taken from the physical gauges on the HX once the system has reached steady state. Observe associated graph to determine steady state.

2. Record the inlet temperature of cold water stream from TI-15.

3. Record the outlet temperature of cold water from TI-13.

4. Record the outlet temperature of the steam line from TI-14.

5. Record the steam pressure using PG-13 (*Figure 18*)

6. Measure and record from indicated instruments shown in *Figure 20* to compare readings from apparatus and Delta V software.

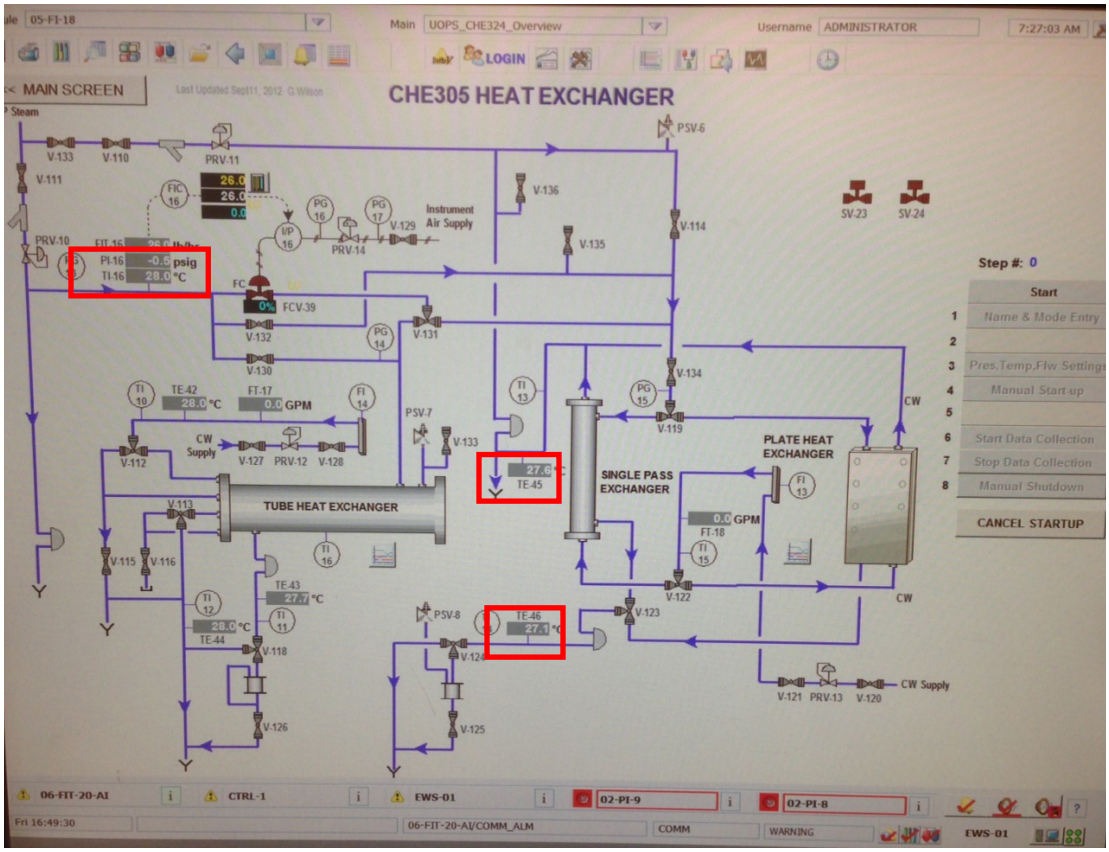

Figure 27. Location of Delta-V temperature indicators for single column and plate heat exchanger.

Table 3. Instrument and measurement of Delta V software for single column and plate heat exchanger.

Delta-V Gauges	Measure
PI-16	Inlet Steam Pressure
TI-16	Inlet Steam Temperature

TE-45	Outlet Cold Water Temperature
TE-46	Outlet Steam Temperature

7. For each HX run measure the condensate flow rate by recording the time it takes to reach the mark on the glass (desired level).
    a. This is done by closing valve V-125 to allow condensate to build up in trap
    b. The volume up to the mark is 250mL

Figure 28. Single and plate HX condensate trap

Section D: Shutdown procedure

- Follow Part I D for shutdown procedure

Part III. Plate Heat Exchanger

1. Modify valve pathway for Plate heat exchanger.
    a. Valve V-122 should be turned 90° Clockwise (CW) to direct cooling water to plate HX
    b. Slowly open Valve V-121 and adjust until flow in FI-13 reaches 80%
    c. Do not change V-131, this pathway supplies steam to both hair pin and plate
    d. Valve V-119 should be turned 90° CW to direct steam into to plate HX
    e. Valve V-123 should be turned 180° Counter-clockwise (CCW) to direct steam out of plate HX
    f. Do not change V-124, this directs condensate through trap
2. Open bypass valve V-132 to prepare system for condensate flush
3. Repeat steps Part I A Steps 10-13 to start up steam
4. Restart Delta-V by following Part I B
5. Repeat steps Part I C for recording data and determining condensate flow
6. Repeat steps Part I D to shutdown system

Checklist for Shut Down

- ❑ All valves are closed: V111, V112, V113, V115, V116, V118, V122, V123, V124, V125, V126, V127, V128, V129, V130, V131, V133 and V134
- ❑ Delta-V system is back on main menu
- ❑ There is no condensate in either of the traps
- ❑ PG13 reads zero psig
- ❑ Let the cool water line run to cool down the system

Troubleshooting

Note: Whenever steam is introduced to any unit sitting at room temperature, precaution should be taken to absolutely minimize the **steam hammer effect**. **Steam hammer** can rupture piping accessories and cause severe damage to equipment and people around. You will recognize steam hammer by the ever present 'knocking' sound as steam is being introduced. A painstakingly slow and periodic increase in the steam valve will ensure adequate protection for the removal of condensate and the dangers associated with steam hammer.

- Once the steam hammer is gone more steam can now be introduced slowly. It is suggested that the student will start by selecting their lowest water flow and then investigate a range of steam pressures.
- During the operation of the equipment, remember that during start-up and continuously thereafter, air must be purged from the shell-side, otherwise very poor heat transfer will result.
- It is important to ensure that the heat exchanger has reached steady state before final experimental measurements are taken. All data collected should reflect actual lab times for each run.