Safety

- Read this document in its entirety before operating this equipment.
- Safety glasses must be worn when operating this equipment
- Never leave this equipment operating unattended
- The control valves are very slow to respond – keep this in mind when controlling the flow of liquid. In an emergency you can stop the water flow by manually closing the main water supply valve.
- The computer is not connected to the network.
- Do not open the data file while the system is running, doing so will stop the data log.
- Pay close attention to the water level in the main tank, it is very easy to overfill.

Equipment Description and Overview

Detailed equipment specifications may be found at the end of this document.

Briefly, the mixing tank is filled to approximately 40 – 60 % full with water which is at roughly room temperature. Once the tank is filled to the desired level the water is pumped from the tank up to the steam heat exchanger which is located above the system, see the white and yellow double pipe in the ceiling above the apparatus. The heat exchanger is heated using building supplied steam at approximately 8-10 psi as displayed on the steam pressure and temperature gauges in line with the steam pipe located above the apparatus. The heated water \textit{flows into the tube side of the shell and tube heat exchanger where, once the water has been heated to a steady-state temperature, is cooled by running cooler water through the shell side of the heat exchanger.} Tube and shell flows are controlled by actuating the flow controls valves using the Opto software. Temperatures are measured throughout the system and displayed on the Opto control display. All data points shown on the Opto display are automatically saved to a data file. The sample rate is once every second.

Startup

1. Log on to the computer using the user name and password posted on the monitor
2. Open the Opto Control Shell & Tube program by clicking on the Shell & Tube Opto Control Icon located on the desktop.
3. Close the event log viewer window.
4. If the event log viewer keeps popping up and fills with lines of error messages contact the lab manager before proceeding.
5. Click on the Start Opto Control text to start the software.
6. **About the Software:**

The Opto control software is configured so that the system may be operated as a heat exchange experiment or as a control experiment. When operating the system as a heat exchange experiment the system is controlled using the Manual Mode Controls in the upper left-hand corner of the main window. Temperature data is displayed on the left side of the main window. The controls listed under Tube Flow Control and Shell Flow Control are for PID control when running a control experiment.

When the software starts the system is in Manual mode, indicated by the capitol M to the right of the **PID Mode text**. Clicking on the PID mode text will activate the PID mode control. Do not activate the PID mode unless you are running a control experiment.

*When running a PID experiment you MUST meet with the lab manager prior to operation to review software operation.*

When running a heat-exchange experiment the PID Mode display must read M.

7. In the manual mode section of the software open the shell valve control 100% Now using the software open the tube valve control 100%

8. Open the shell flow tank feed valve located just above the lip of the tank.

9. Open the recycle valve 3-4 turns (Red handle on *horizontal* section of yellow pipe going to mixing tank)

10. Open the pump outlet valve 100 % (Red handle on *vertical* section of yellow pipe going to heat exchanger)

11. Close the shell flow drain valve (green ball valve located behind the tank) Verify that the clear hose connected to the shell flow drain valve is inserted into the vertical drain pipe.

12. Close the tank drain valve (Ball valve with yellow handle located in the tank drain pipe)

13. Open the main water supply valve (Red handle on vertical green pipe next to black pipe)

14. Water should now flow into the mixing tank.

15. Monitor the tank flow – fill to about 60% full. Pay careful attention to this step – it is easy to overfill the tank! Control the flow into the tank using the shell flow valve control on the software. Keep in mind the control valves take a minute to actuate. If the Opto controlled valve is not responding fast enough, stop the water flow using the manual main water valve.

16. Once the tank is filled to the desired level, close the shell flow tank feed valve located just above the lip of the tank.

17. Now open the shell flow drain valve located behind the feed tank and close the shell valve (set to 0%) in the manual mode section of the Opto control window. This will prevent water pressure from building up in the plastic water filter housing.

18. Verify that the recycle valve and pump outlet valve are open.

19. Verify that the tube valve is set to 100% open on the computer.

20. Start the pump buy pushing the start button on the shell and tube pump control unit mounted on the wall just west of the double pipe heat exchanger. You may need to push the Stop button in all the way before you can push the Start button in.
21. At this point, with both the recycle valve and pump outlet valve open only part of the water that exits the pump is flowing into the heat exchanger, the remainder of the flow from the pump outlet is being recycled to the feed tank. To increase the amount of water going to the heat exchanger, SLOWLY begin to close the recycle valve. This will increase flow to the heat exchanger BUT it will also increase the back-pressure on the pump. The outlet pressure or back-pressure on the pump is displayed on the pressure gauge at the pump outlet. When adjusting the recycle valve, monitor the pump outlet pressure making sure the recycle valve is always open enough so that the pump outlet pressure does not exceed 50 PSI as displayed on the pump outlet pressure gauge. The ideal condition would be to operate the system with a slight recycle flow so that flow rate is adequate for your experiment and the pump outlet pressure is in the 20 – 50 psi range.

22. Allow the system to heat to steady state, this may take some time.

**Running Cooling Water after the System has Reached Steady State.**

23. Open the Shell Flow Drain Valve – ball valve connecting shell flow outlet to clear tubing which is inserted into the drain stand pipe - and set the shell valve control on the computer to the desired set point. The shell flow is the cooling circuit. By opening this valve cooling water flows through the shell and tube heat exchanger. Flow is controlled using the shell valve control.

24. **Monitor the pump outlet pressure** as displayed on the pressure gauge on the pump outlet pipe, the pressure will increase as the tube valve is closed. Do not allow the pump outlet pressure to exceed 50 PSI. In order to keep the outlet pressure below 50 psi you will need to open the pump recycle valve. As the recycle valve is opened the pump outlet pressure is reduced. Remember that opening the recycle valve does not significantly affect flow through the heat exchanger.

25. **Notes on Tube Flow Control.** Both the shell and tube flow valves are controlled by setting the valves to a percent open. This percent open setting is not linear. The tube valve control requires close attention as it is possible to stop the flow in the tube circuit even though the tube valve percent open is greater than zero. Below is a list of tube valve percent open setting and the corresponding flow rates and pump outlet pressure reading. It is critical that the recycle valve be opened at least enough to allow enough flow out of the pump in case you inadvertently close the tube flow valve and dead-head the pump.

- Maximum Tube Flow is approximately 35 GPM
- A tube flow setting of ~ 60% open will result in a tube flow rate of ~ 20 GPM and 40 psi pump output pressure.
- 50% open ~11 GPM~46 psi
- 42% open is about the low limit for measurable tube flow at ~ 4.5 GPM, at this setting adjust the pump recycle valve as needed to maintain the pump output pressure below 50 psi.
Shutdown Procedure

1. Stop the pump
2. Close the main water supply valve
3. Open the tank drain valve
4. Open the pump recycle valve
5. Close the valves in the Opto software
6. Exit the Opto control program

Viewing and saving the data

1. Once you have exited the Opto program, open Excel
2. In Excel go to: Open, then navigate to the data folder, C:\Data Shell & Tube. In the bottom of the Excel window click on the drop-down window and select All Files, the data files should now be displayed. The data files are organized by date.
3. Double-click on the file you wish to open. The Text Import Wizard will open. Select delimited then click Next, then select Comma delimited, select Next, select the General data format option and then select Finish. The data should now be displayed in Excel.
4. Save this data to a flash drive after each lab.