Determining Global Heat Transfer Coefficients for a Series of Heat Exchangers

Team 1: Mason Phelps, Kyra Boudreaux, and Vu Tran

Instructor: Dr. Gregory Griffin

CHE 3104 – Cycle 1

October 4th, 2021

LSU College of Engineering
Cain Department of Chemical Engineering

LSU

The Old and The New

- Improvements on the early cooling methods.
- Why should chemical engineers understand refrigeration systems?

- Reference 1

Goals of our Experiment

- Measure the heating and cooling rates of the heat exchangers at different flow flow rates.
- Use these data to determine the global heat transfer coefficient for each exchanger studied.
- Determine whether these coefficients are dependent on either flow rate, average temperature of the exchanger, or both.

- Reference 2

Heat Transfer Rate Equations

- Hot Stream Heat Transfer Rate: $q_H = \dot{m}_H C_{p,H}\left(T_{H,out} - T_{H,m}\right)$ *Eqn (1)*
- Condensing Steam Heat Transfer Rate: $q_H = -\dot{m}_H \lambda_{vap}$ *Eqn (2)*
- Cold Stream Heat Transfer Rate: $q_c = \dot{m}_c C_{p,c}\left(T_{c,out} - T_{c,m}\right)$ *Eqn (3)*
- Adiabatic Conditions: $q_H = -q_c = q$ *Eqn (4)*

- *Where: any variable X_H references the hot stream of the exchanger while any variable X_C references the cold stream of the exchanger. The heat transfer rate is q. The mass flow rate is $\dot{m}$. The heat capacity at constant pressure is C_p. T represents temperature of the stream.*

- Reference 3

Heat Exchanger Correlation

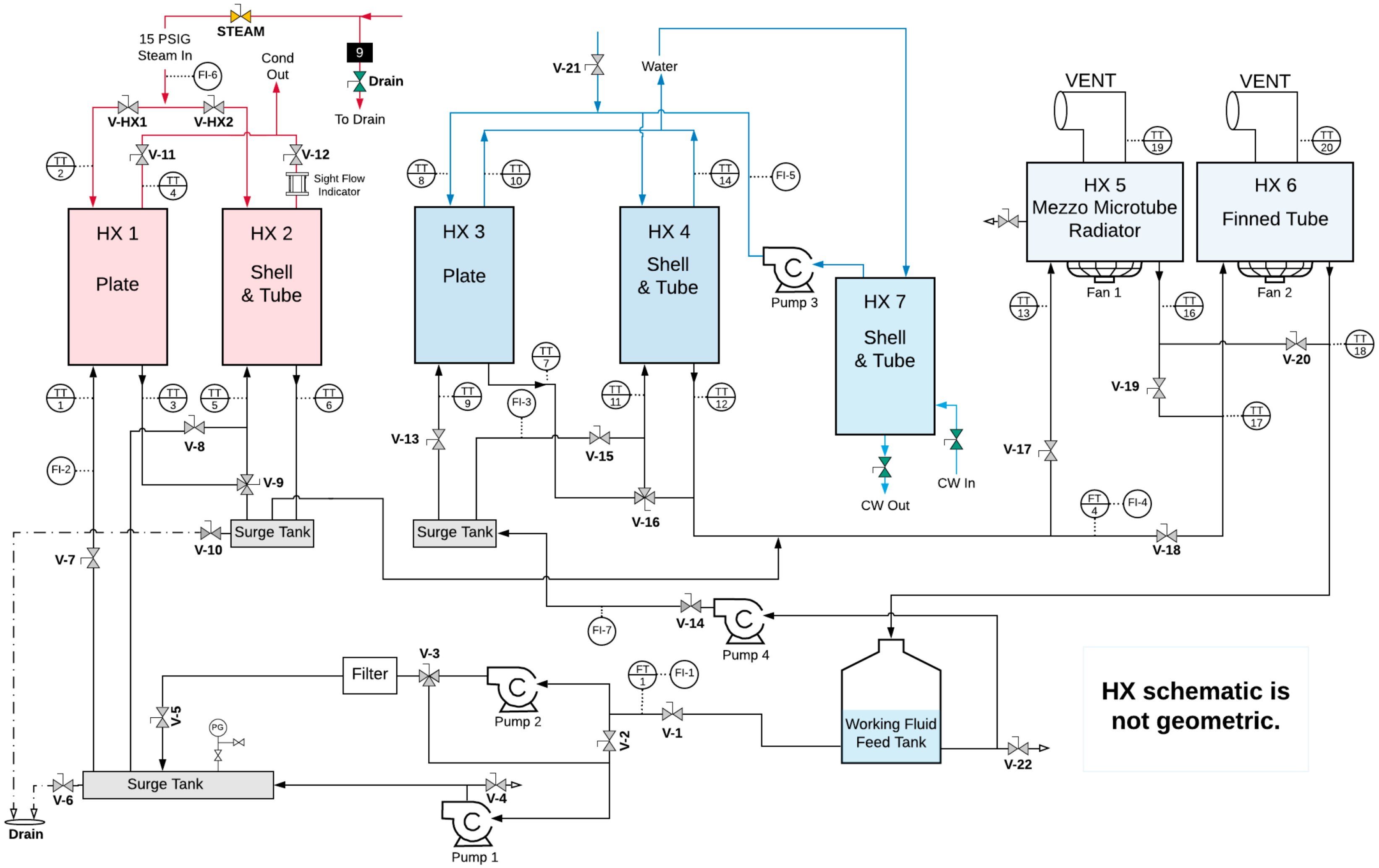
- Log Mean Temperature Difference: $\Delta T_{lm} = \frac{(T_{H,in}-T_{C,out})-(T_{H,out}-T_{C,in})}{\ln\frac{T_{H,in}-T_{C,out}}{T_{H,out}-T_{C,in}}}$ *Eqn (5)*
- Heat Exchanger Correlation: $UA = -\frac{q}{\Delta T_{lm}}$ *Eqn (6)*
- Reservoir Temperature Behavior: $\dot{m}C_p(T_{in} - T_{out}) = \rho C_p V \cdot \frac{dT}{dt}$ Eqn (7)

- *Where: any variable X_H references the hot stream of the exchanger while any variable X_C references the cold stream of the exchanger. T_{lm} is the log mean temperature difference between four streams. The global heat transfer coefficient is UA. The heat transfer rate is q. The mass flow rate is $\dot{m}$. The heat capacity at constant pressure is C_p. ρ is density of the reservoir fluid. V is the volume of fluid in the reservoir. Lastly, $\frac{dT}{dt}$ is the time derivative of the reservoir temperature.*

A Tour of the Heat Exchanger Unit

3 Sections

- Working Fluid
- Heat Exchangers (7)
- Pumps (4)
- Many Valves & Instruments



HX schematic is not geometric.

- Reference 4

A Tour of the Heat Exchanger Unit

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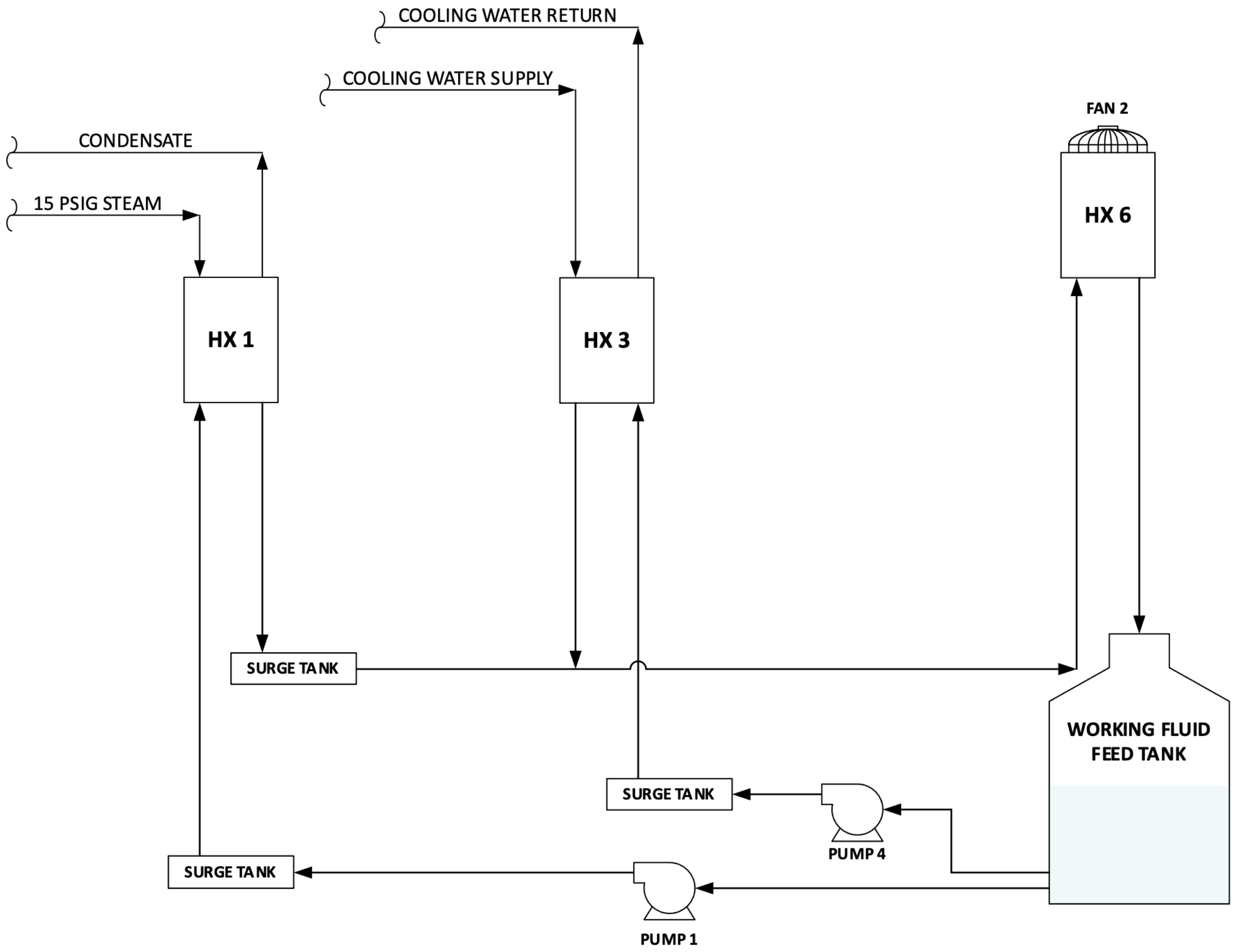
- Loop 1



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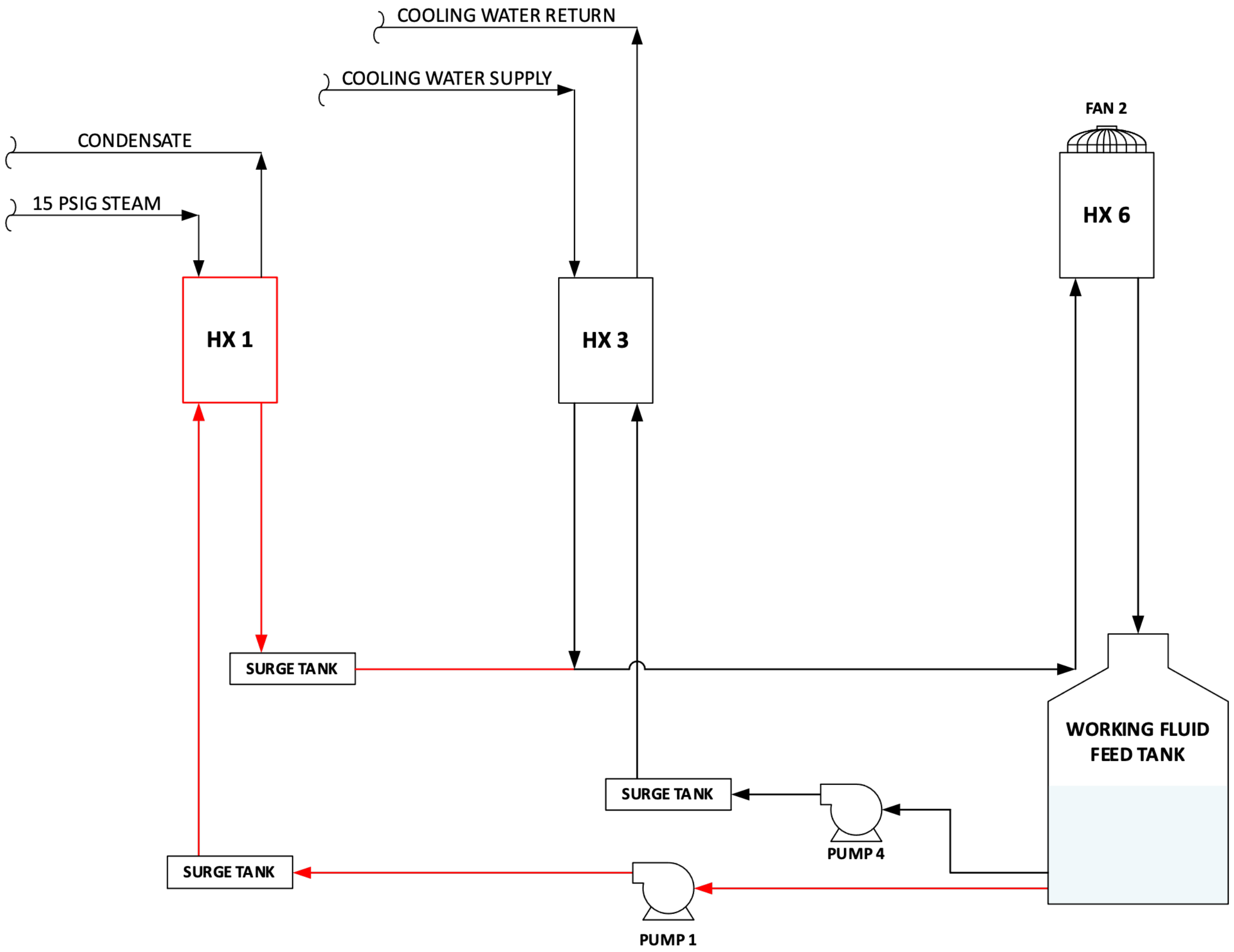

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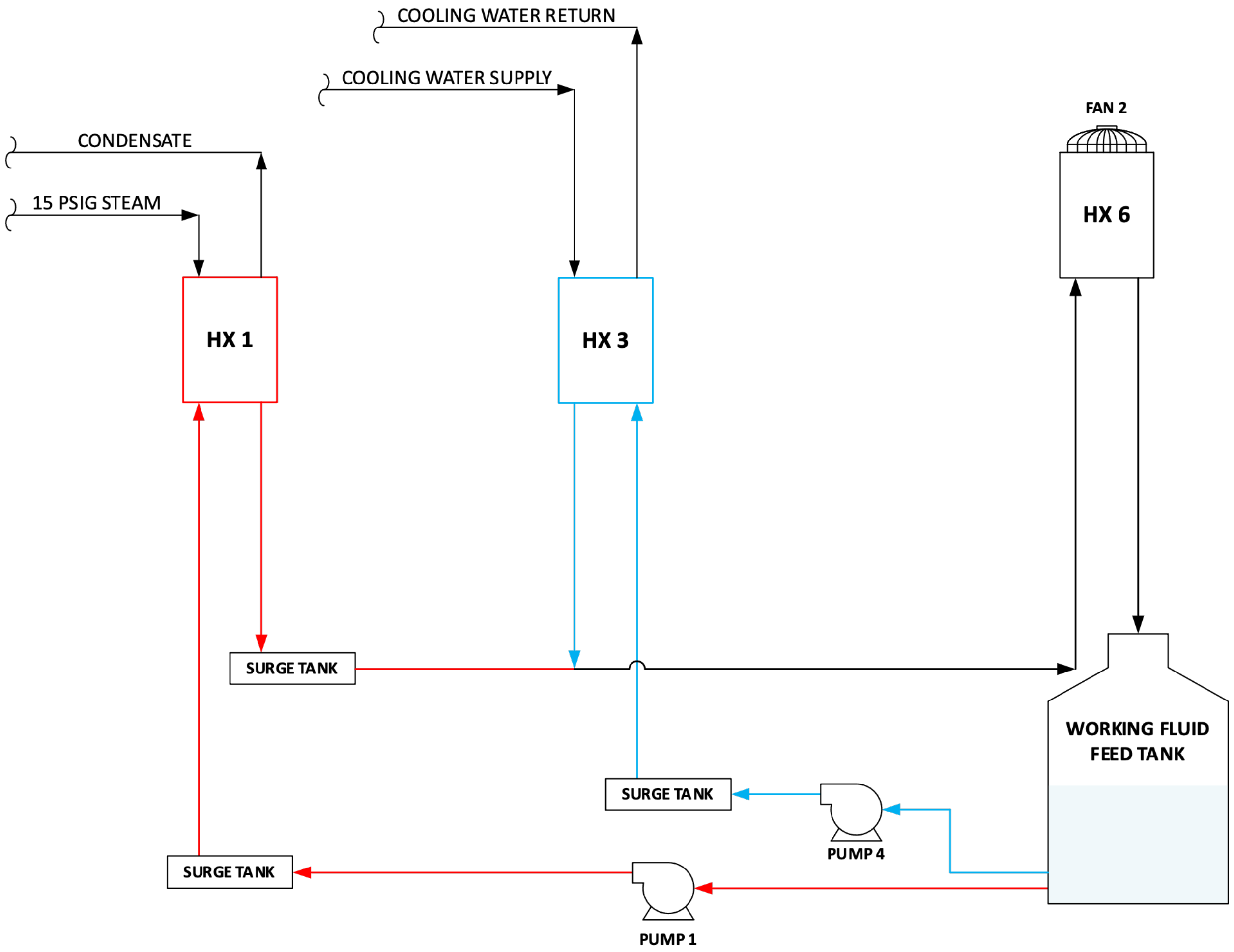

A Tour of the Heat Exchanger Unit

3 Sections

- Working Fluid
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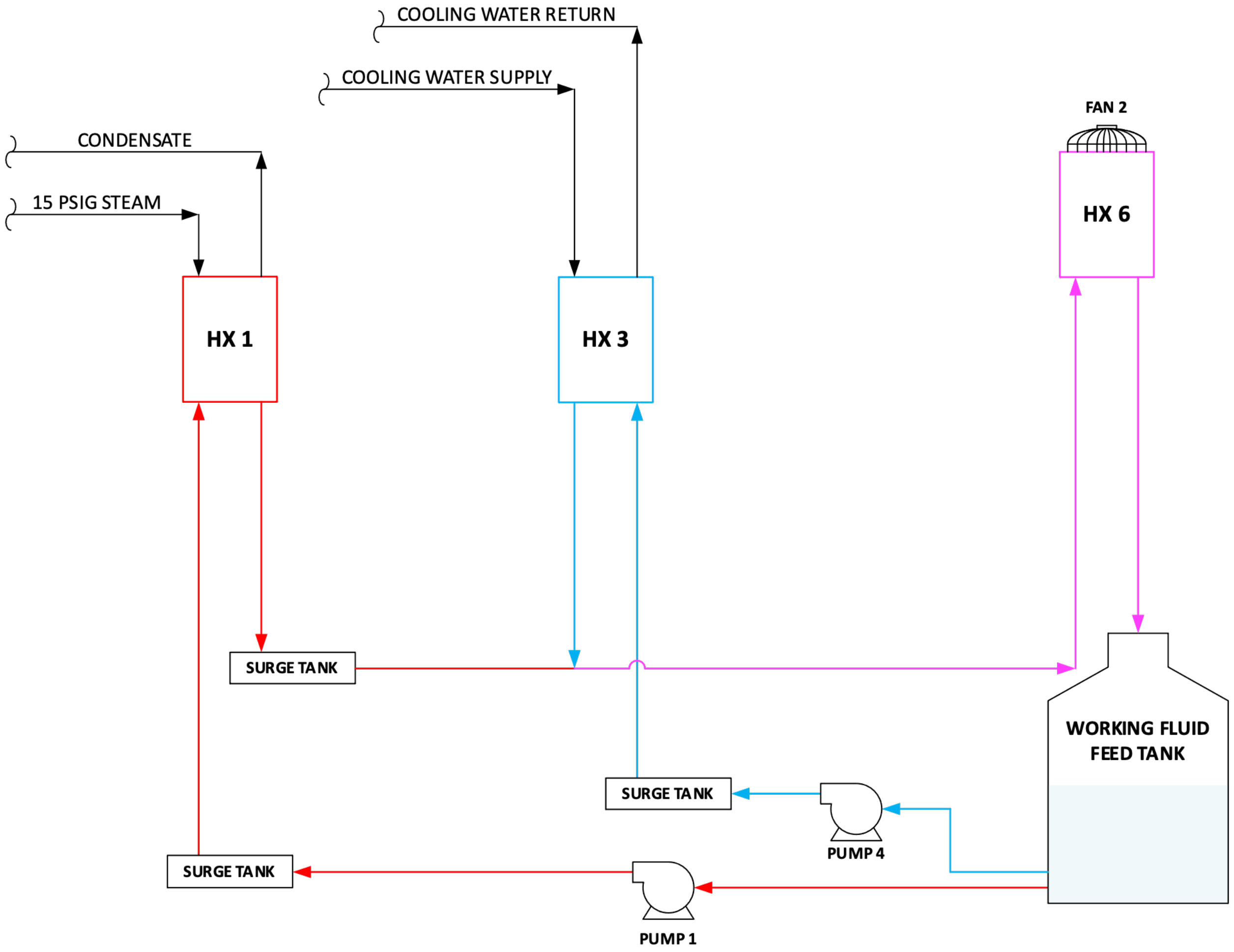
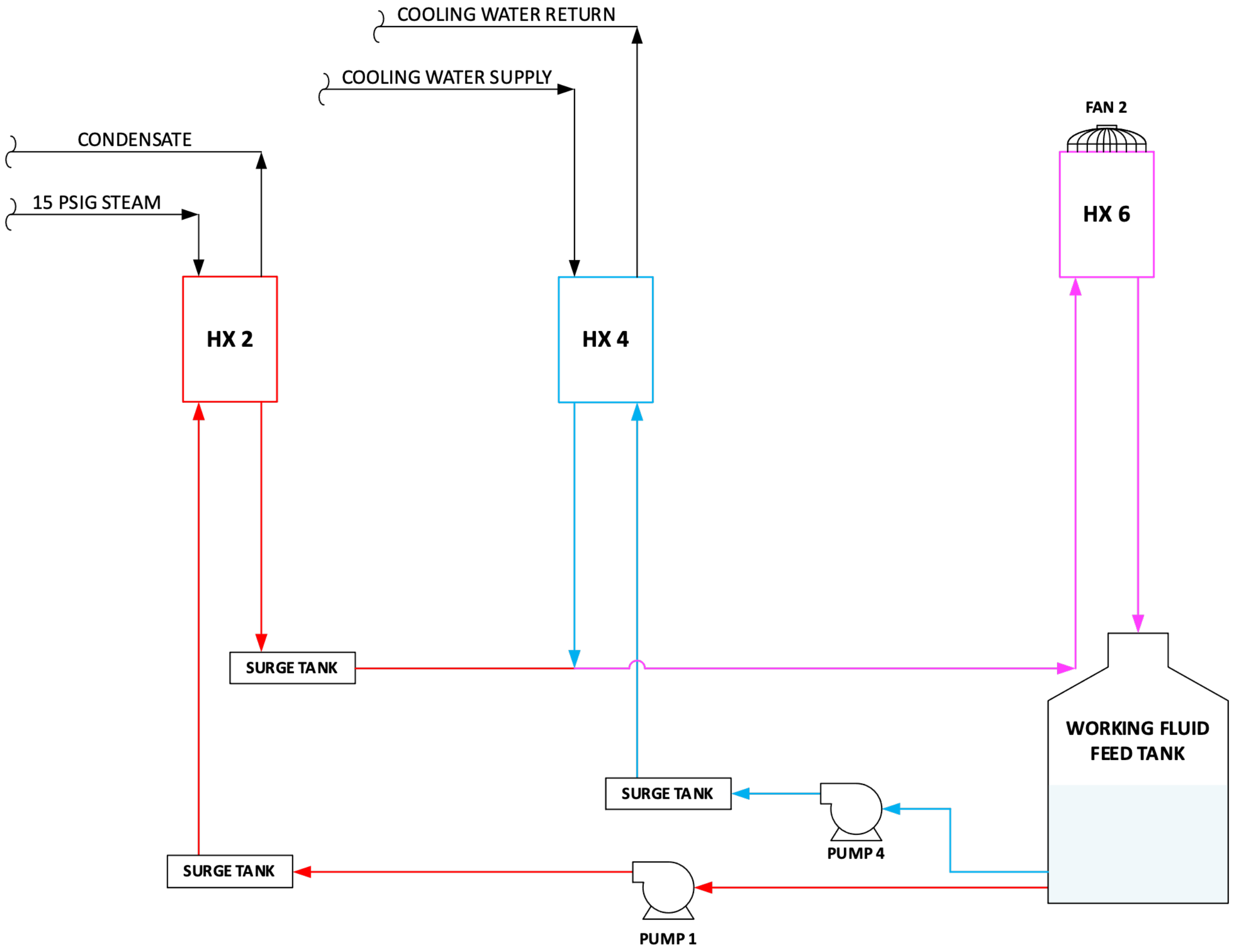
- Pumps (4)
- Many Valves & Instruments
- Loop 1
  - Two trails were run.
  - Reproducibility



A Tour of the Heat Exchanger Unit

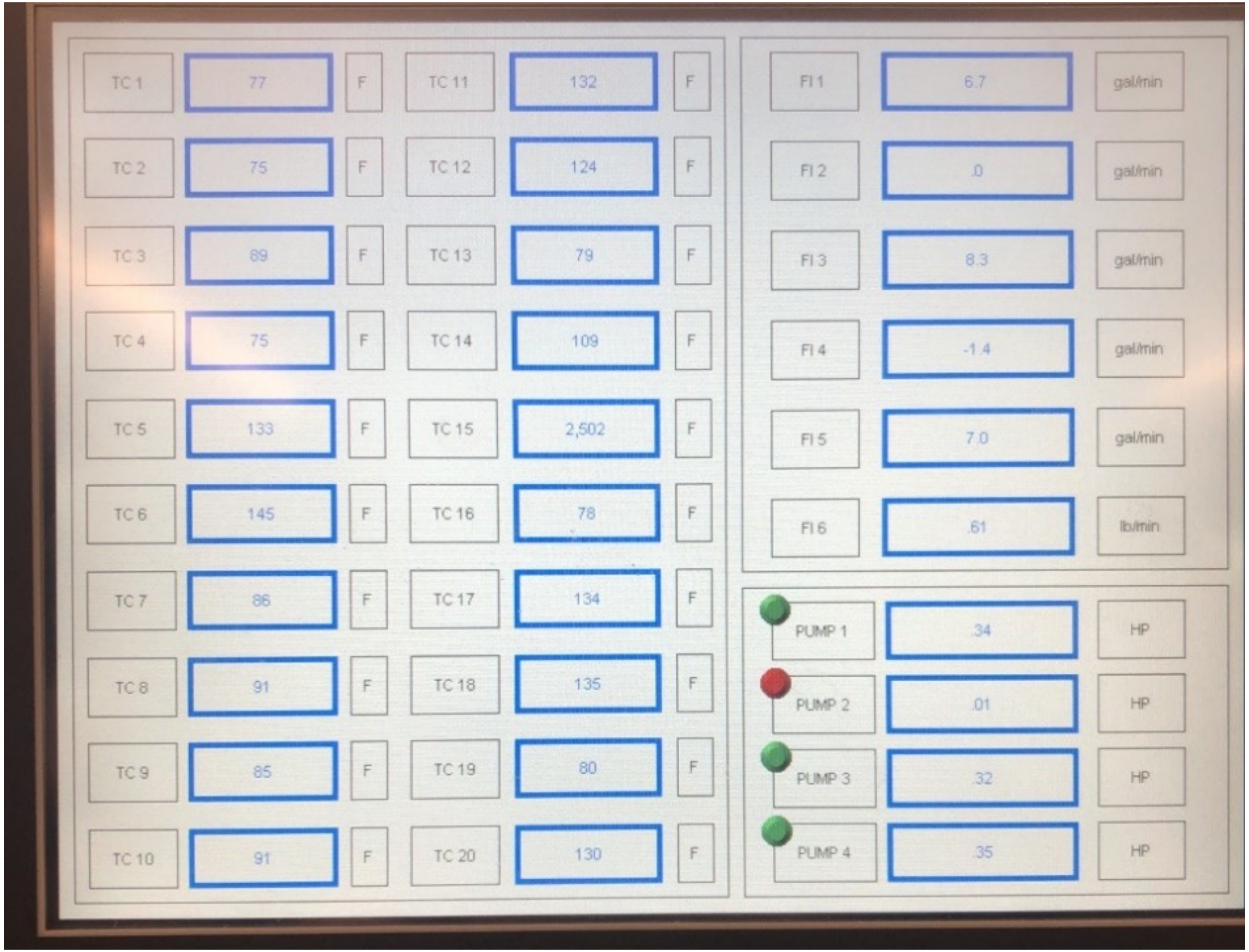
3 Sections

- Working Fluid
- Heat Exchangers (7)
- Pumps (4)
- Many Valves & Instruments
- Loop 2
    - Only one trial was run.
    - Not Reproducible.

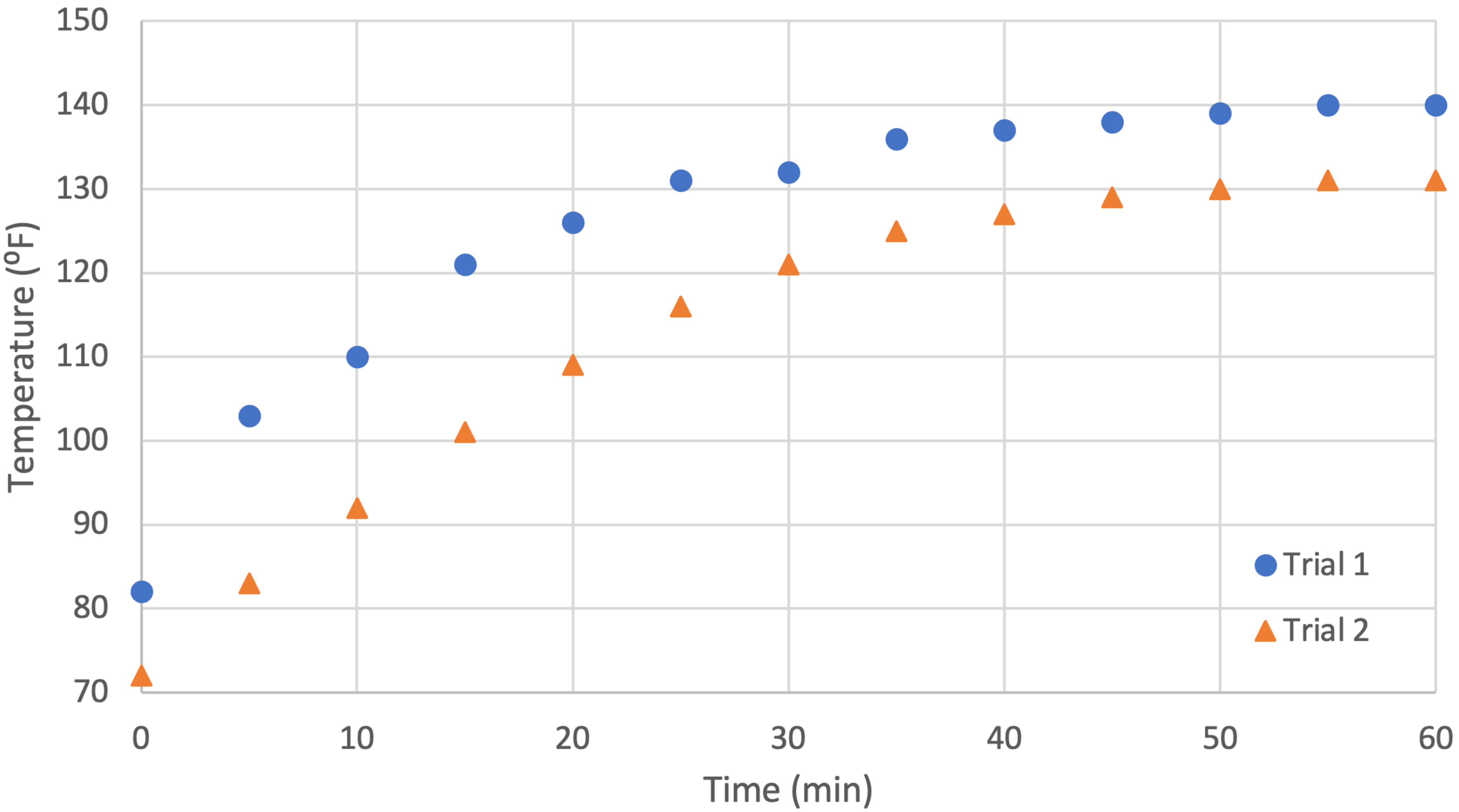


Data Collection

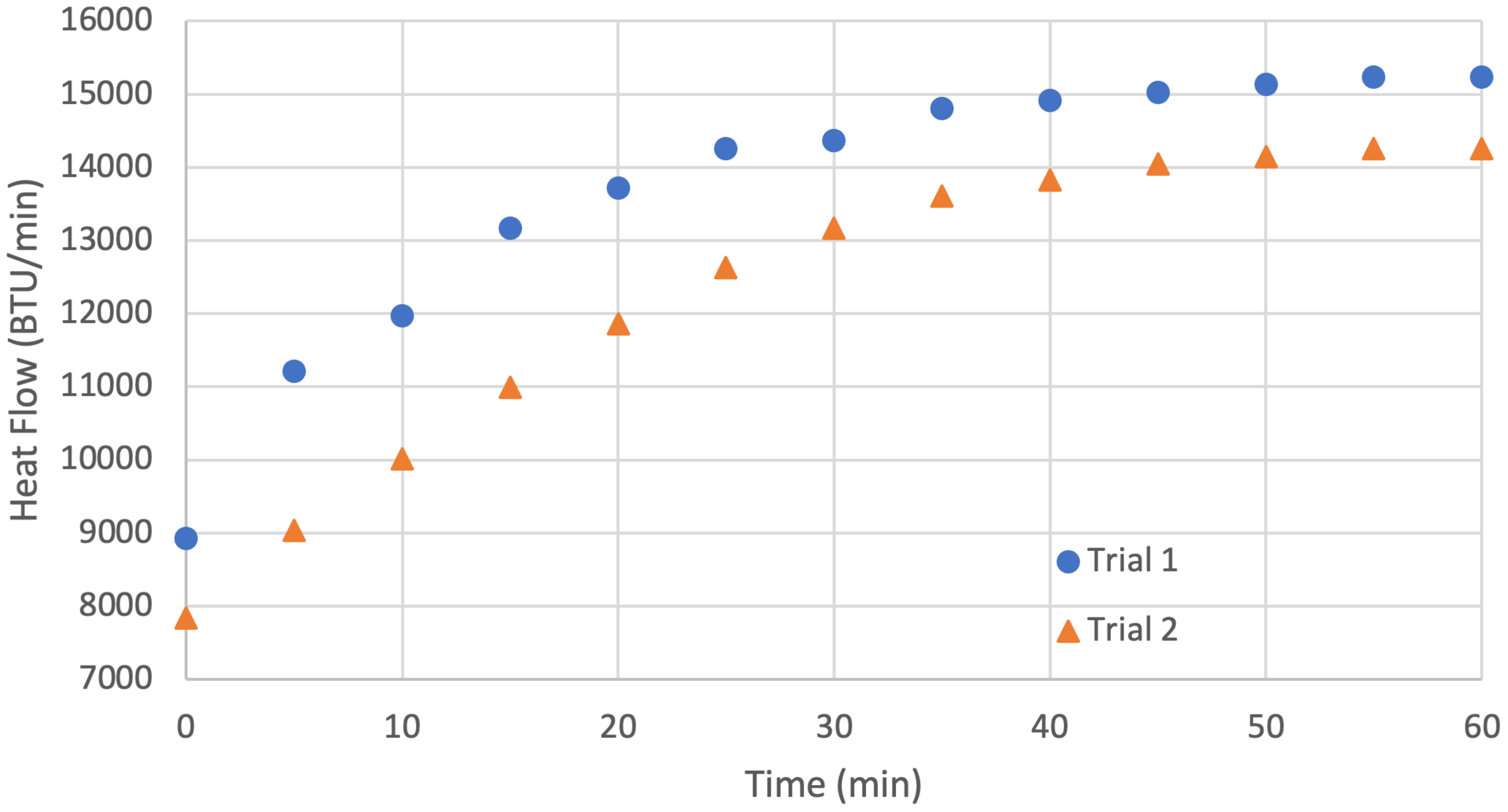
- The Control Panel was photographed every 5 minutes.
- TC 15 was measured using an infrared thermometer.



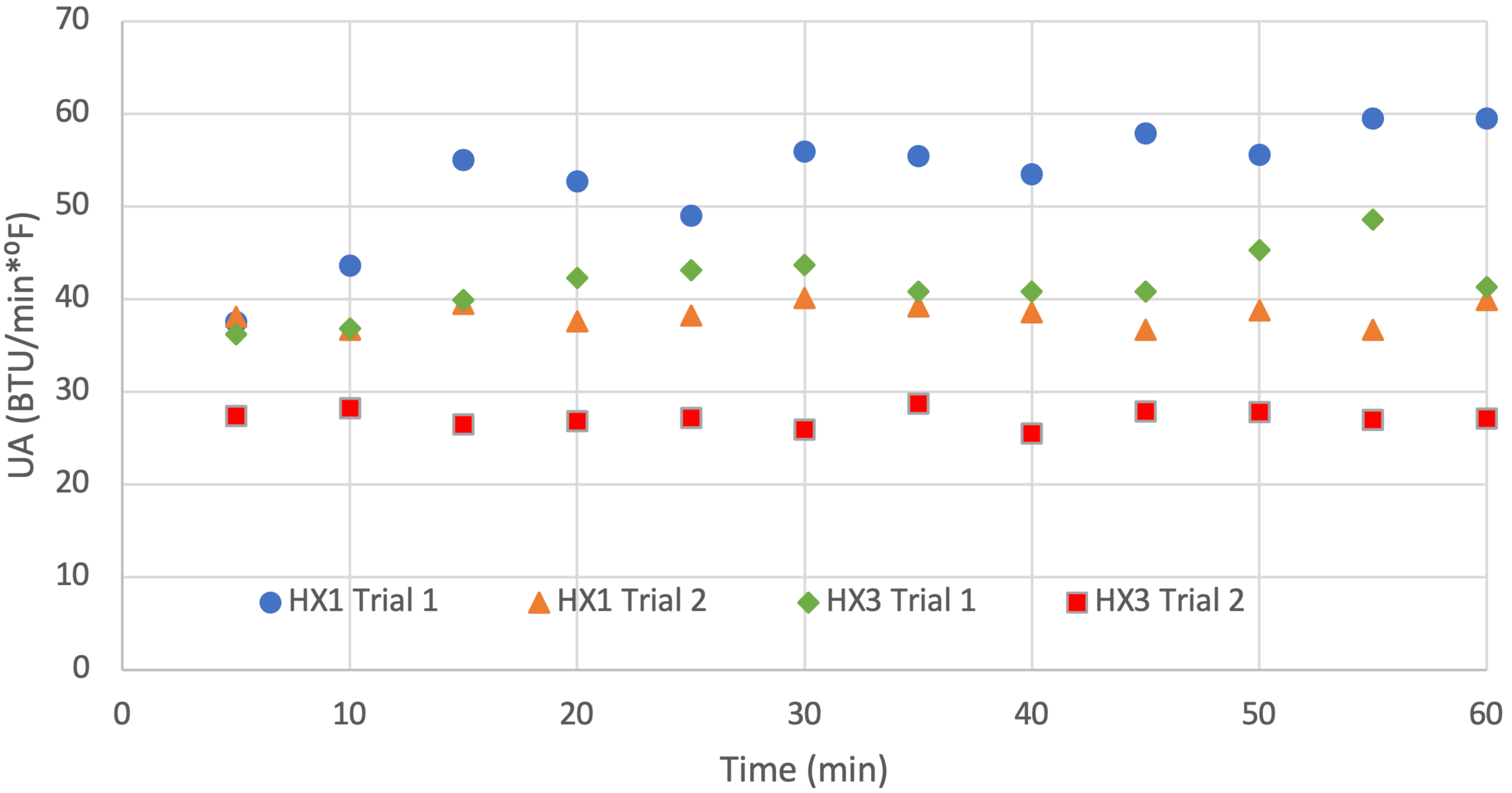
Loop 1 Results — Reservoir Temperature vs. Time



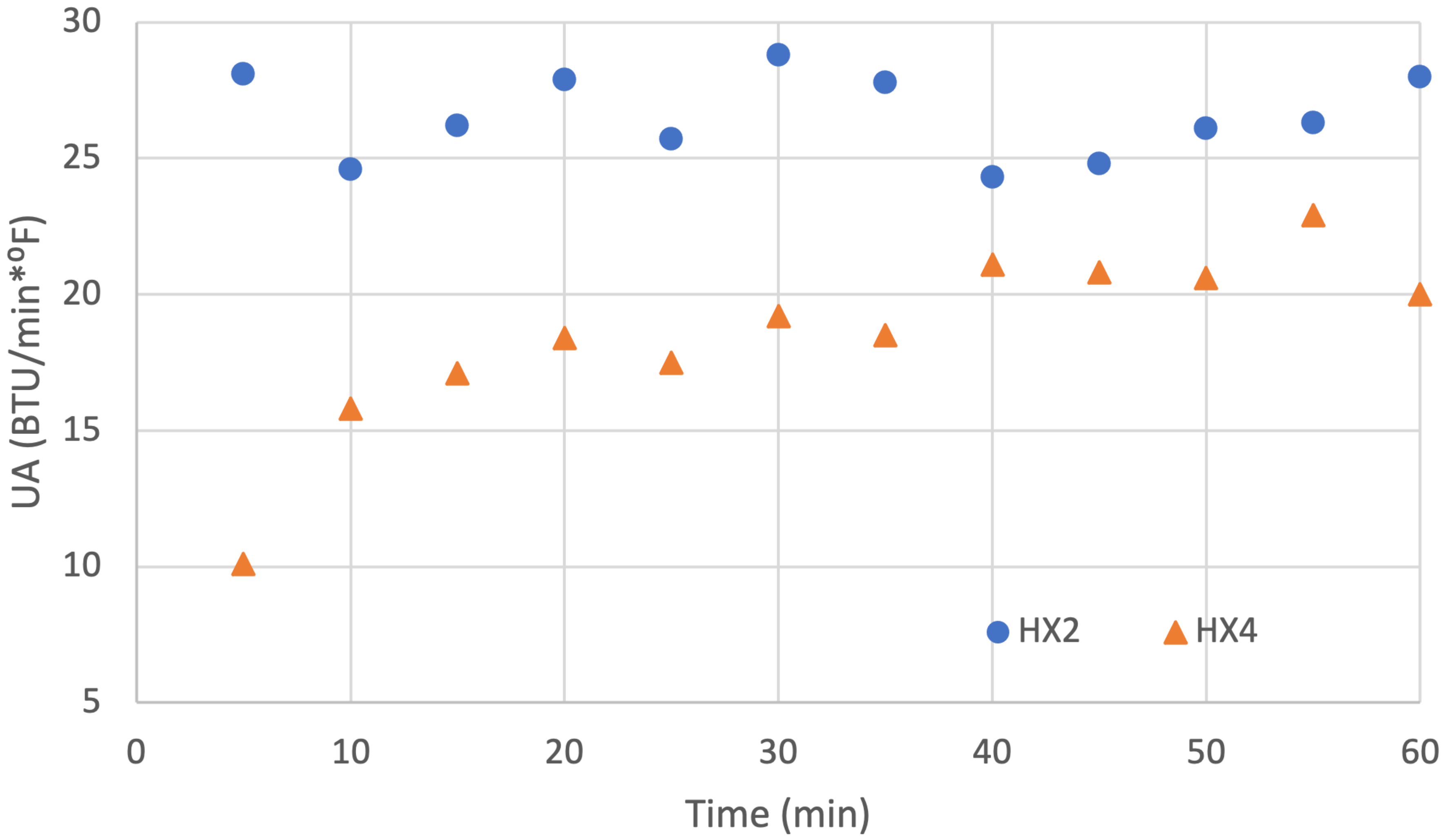
Loop 1 Results — Heat Flow (q) vs. Time



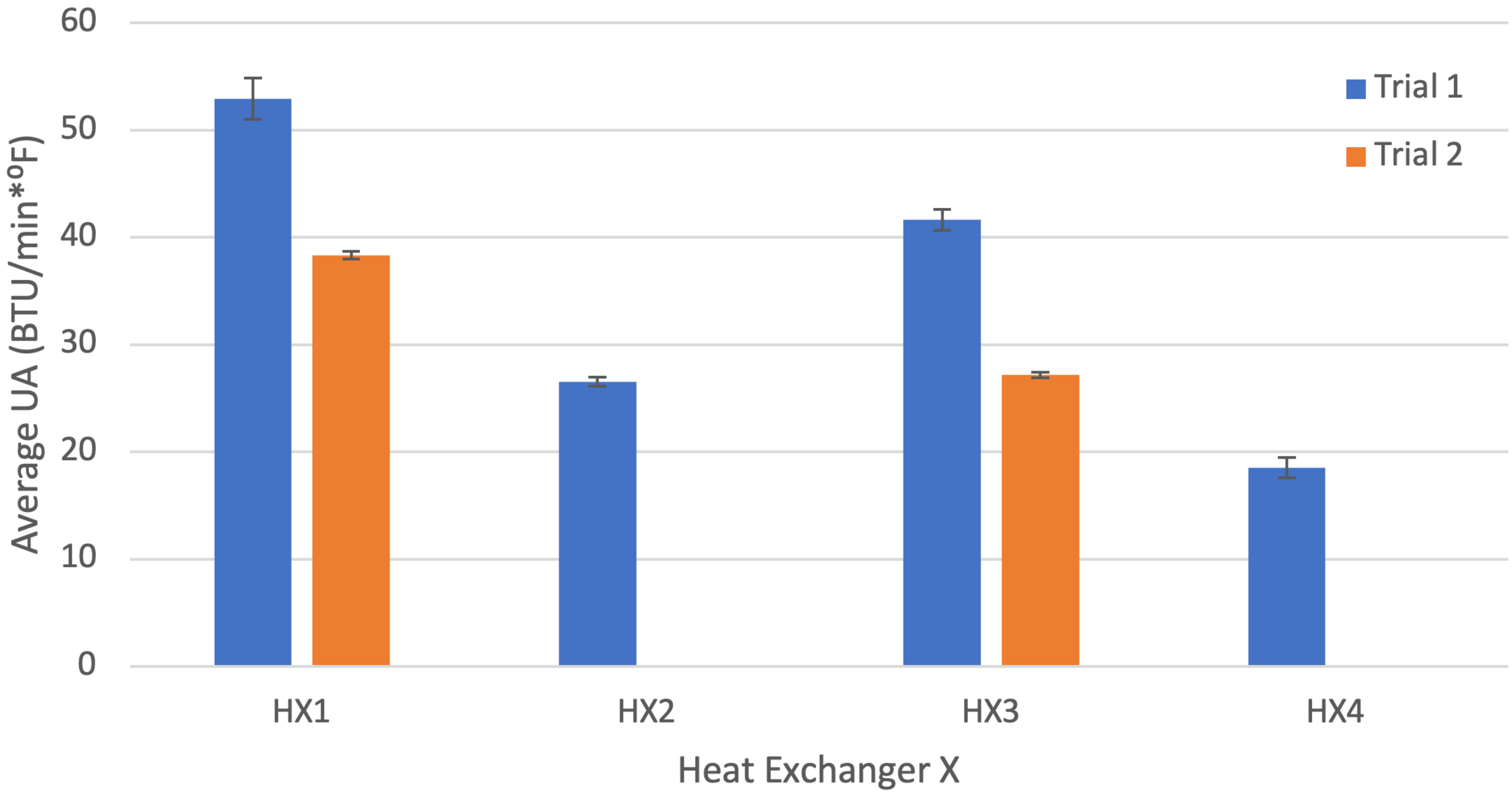
Loop 1 Results — UA vs. Time



Abridged Loop 2 Results — UA vs. Time

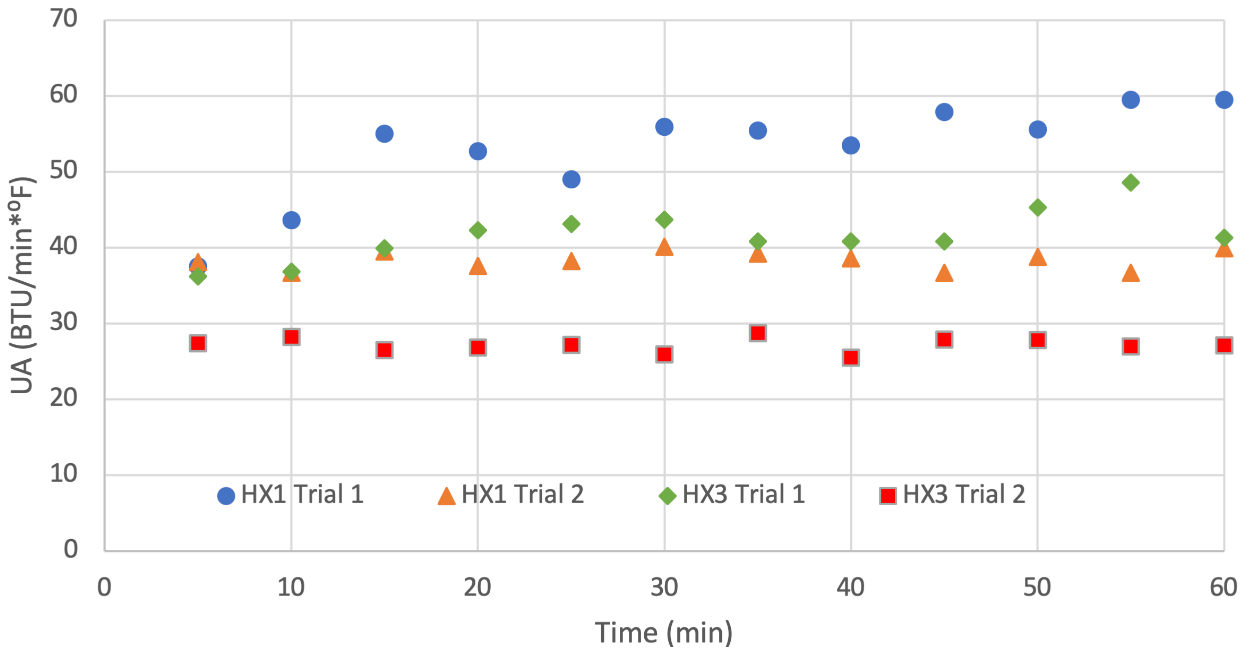


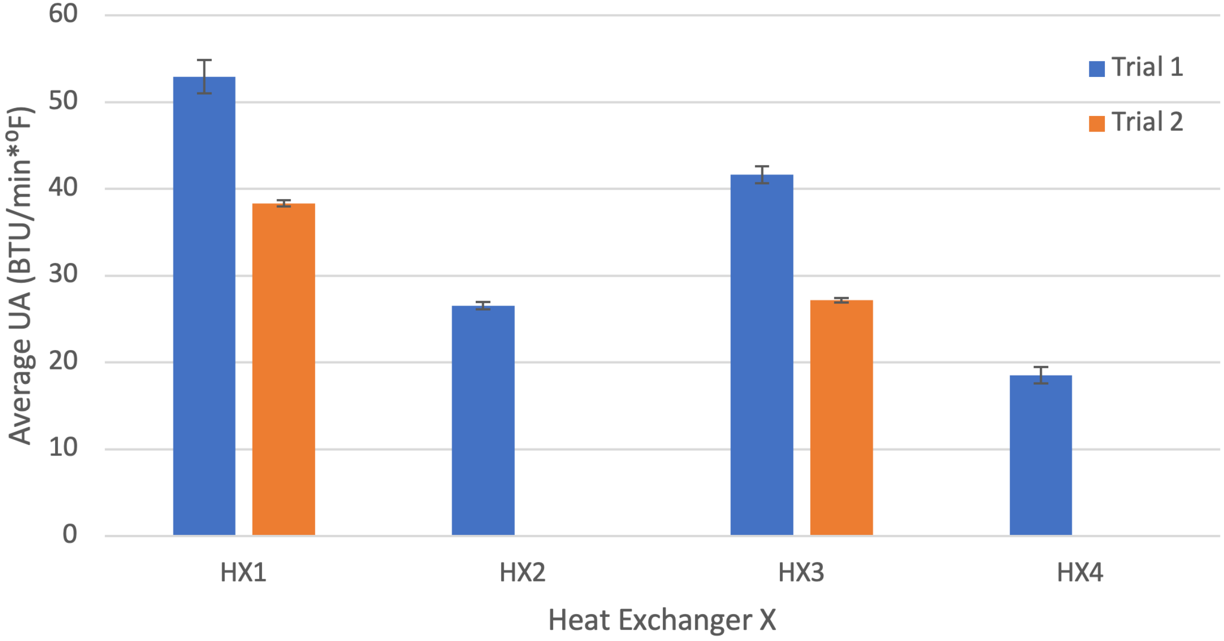
Total Results — UA Summary



Our Successes

- Measure the heating and cooling rates of the heat exchangers at different flow flow rates. **Successful.**
- Use these data to determine the global heat transfer coefficient for each exchanger studied. **Successful.**
- Determine whether these coefficients are dependent on either **flow rate**, average temperature of the exchanger, or both. **Successful.**





References

- Reference 1: Stock Photo Licensed by Microsoft.
- Reference 2: Stock Photo Licensed by Microsoft.
- Reference 3: Reference 4: Griffin, Gregory. “Assignment Memo.” Louisiana State University, 2021.
- Reference 4: Gonzalez, D, and T Schroeder. “Heat Exchanger Network Operating Manual.” Louisiana State University, 2019.

Questions?

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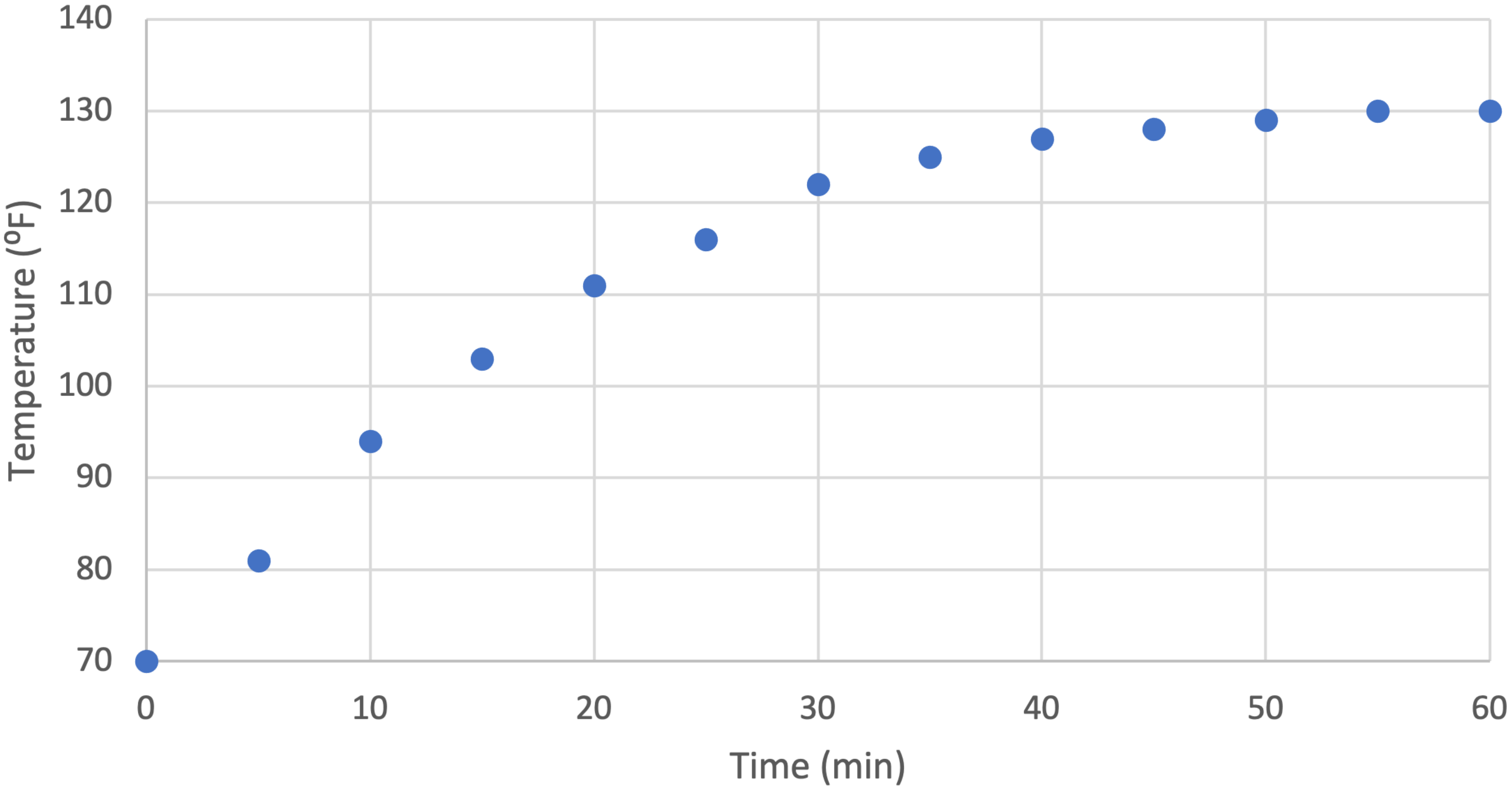
Appendix — Loop 2: Reservoir Temperature vs. Time



Appendix — UA Summary

	HX1	HX2	HX3	HX4
Average UA	45.63	26.55	34.40	18.50
SD	8.77	1.54	7.78	3.29
SD*n^0.5	2.53	0.44	2.25	0.95

Appendix — UA per HX per Trial

	HX1 trial 1	HX1 trial 2	HX2	HX3 trial 1	HX3 trial 2	HX4
avg	52.925	38.342	26.550	41.633	27.167	18.500
stdev	6.594	1.228	1.537	3.397	0.925	3.294
s/sqr(n)	1.904	0.355	0.444	0.981	0.267	0.951

Appendix — Nonadiabatic Concerns

HX3		
FI7 (WF)	7.55 gal/min	62.967 lb/min
FI5 (Water)	6.3 gal/min	52.542 lb/min
TT9 (WF in)	143 ^oF	
TT7 (WF out)	128 ^oF	
TT8 (Water in)	98 ^oF	
TT10 (Water out)	128 ^oF	
Cp,H (WF)	1.001 BTU/(lb*^oF)	
Cp,C (Water)	1.001 BTU/(lb*^oF)	
qH	-945.449505 BTU/min	
qC	1577.83626 BTU/min	
q	-945.449505 BTU/min	
Tlm	21.64042561 ^oF	
UA	43.68904392 BTU/(min*^oF)	
heat loss? yes		

Appendix — Imbedded Data Worksheet

Microsoft Excel
Worksheet