Biosphere 2 Ocean: Optimization of Heat Exchange

2020

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Project Description

This project was created when concern rose about the high amount of energy needed to keep the Biosphere 2 Ocean (B2O) heated/cooled, and how to optimize the energy usage while maintaining the desired temperature of B2O.

According to the heat equation, a larger difference in temperature between two objects leads to a faster net flow of heat energy. It is more efficient to reheat a certain temperature than to maintain a constant temperature [1]. Therefore, we should let B2O reach it's lowest setpoint temperature, then begin heating instead of constantly keeping the supply water warm.

A thermodynamic relationship can be derived for the B2O system in relation to other parameters using conservation of energy and energy balances.

If we want to optimize the energy consumption, first we have to understand energy usage in the B2O system. We can achieve this by knowing how the parameters directly affect B2O temperature in time, taking into account disturbances.

The goals of this project include:

1. Provide an estimation model from thermodynamics to match the actual data (to a correction factor).
2. Solidify framework for future groups such as creating diagrams, matching data to schematics, and deciphering P&ID's
3. Develop a basic MATLAB GUI simulation of the B2O system

Scientific Challenges

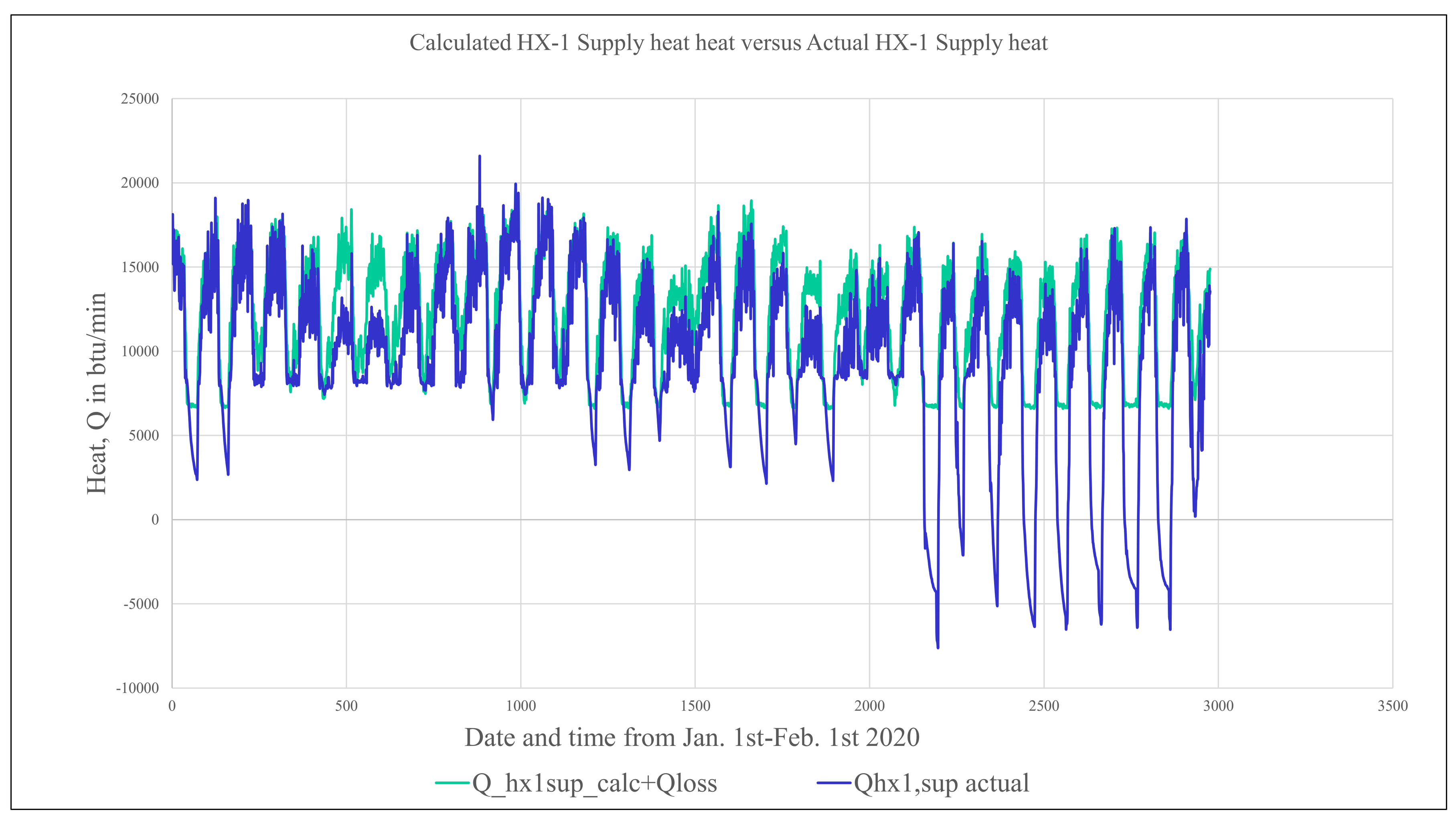
Understanding the thermodynamics of a new system was very enriching, along with the opportunity to learn MATLAB GUI coding. Developing an optimization model is particularly important because energy efficiency efforts ultimately lead to less resource usage for the planet.

Potential Applications

Manual control of many systems can result in unwanted energy losses. With a refined simulation, this model can be applied to any system that exchanges heat to prevent such energy losses.

Methodology

1. Obtain files and login information to SCADA Data center from John Adams, Deputy Director of Biosphere 2. Then, analyze the data and schematics.
2. Develop an energy flow diagram for the B2O system.
3. Draw an energy balance around the B2O and HX-1 and simplify with known variables.
4. Derive an equation relating HX-1 supply temperature to the B2O supply temperature, and other parameters. Then, calculate the heat for each supply line.
5. Verify the derived equation to the actual data and add corrections by graphing both models.
6. Investigate heat losses in the B2O system from disturbances
7. Simulate the derived relationship using a MATLAB GUI program



Calculated heat supply versus actual heat supply of B2O system

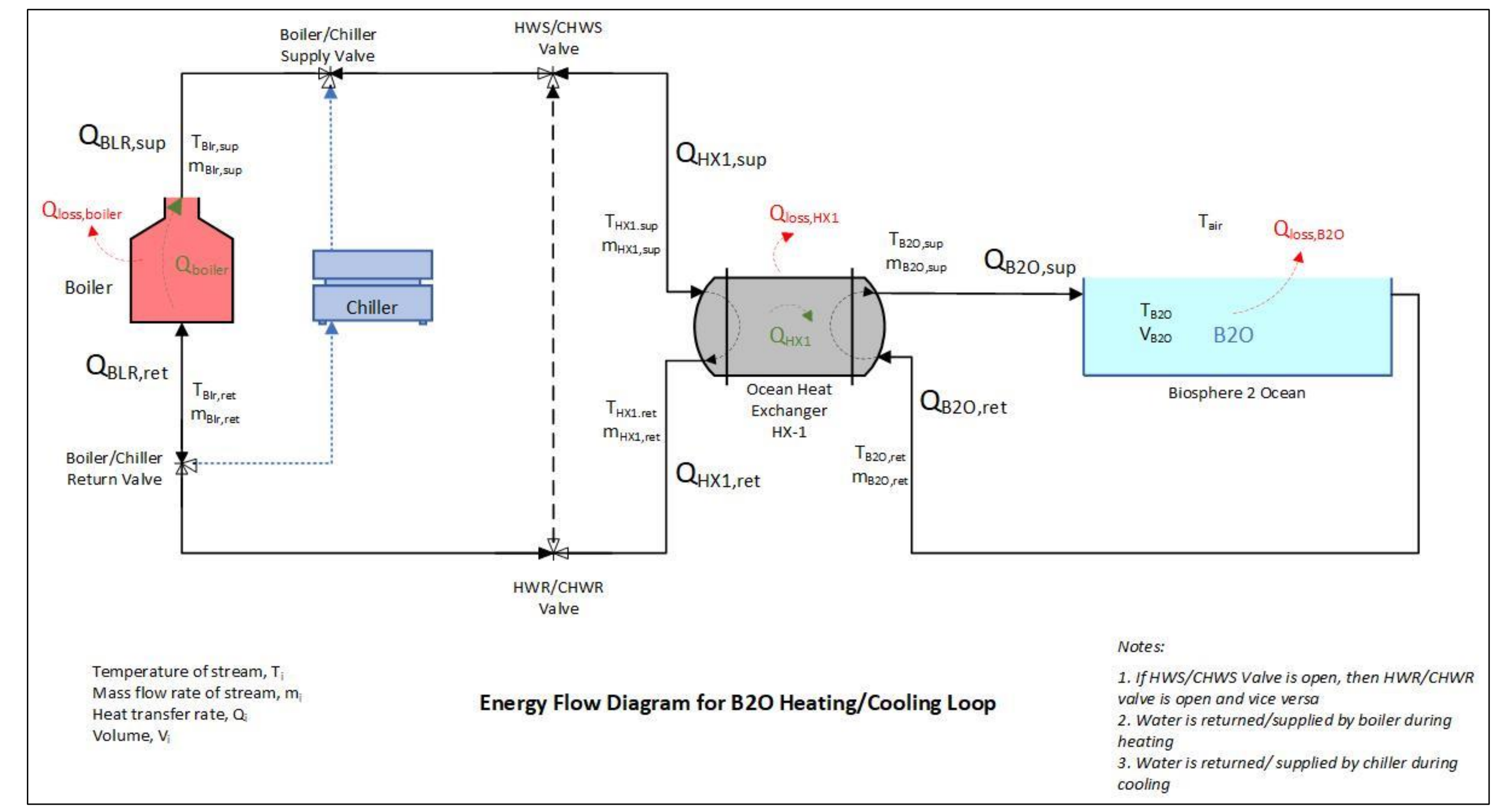
Results

1. Energy balance derivation matches the actual data
2. An accurate estimation model was developed for January-February 2020
3. Framework for project is solidified for future groups
4. Optimization can be achieved through refining model and the MATLAB GUI program by adding disturbances

Glossary of Technical Terms

The heat equation: $u_t = c^2 u_{xx}$
Describes how the distribution heat evolves over time in a material.

Conservation of energy: $Q_{in} = Q_{out}$
A principle stating that energy cannot be created or destroyed, but can be altered from one form to another.



Energy Flow Diagram for B2O Heating/Cooling Loop

$$\boxed{Q_{HX1,sup} + Q_{B2O,ret} = Q_{B2O,sup} + Q_{HX1,ret}}$$

Energy (heat) balance around B2O system with Q=[btu/min]

$$\boxed{T_{HX1,sup} = \frac{m_{B2O,sup}}{m_{HX1,sup}}\left(T_{B2O,sup} - T_{B2O,ret}\right) + T_{HX1,ret}}$$

Equation for the HX-1 supply temperature in terms of known parameters

References

1. Levenspiel, Octave. *Engineering Flow and Heat Exchange*. Springer US, 2014.

Acknowledgments

This project was mentored by Samuel McLaren, whose help is acknowledged with great appreciation. In addition, the help from Dr. Songtao Xie is greatly appreciated.