CHP-Project 1

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From: Mason Averill

Date: 11/8/2019

Re: Thermodynamics II Project 1

The purpose of this memo is to present the results of Project 1 in ME 301 *Thermodynamics II*. This project dealt with combined power-producing cycles (Brayton and Rankine).

The first decision for this project was the overall component diagram. My first solution used only the most basic configurations for each cycle, as seen in Figure 1.

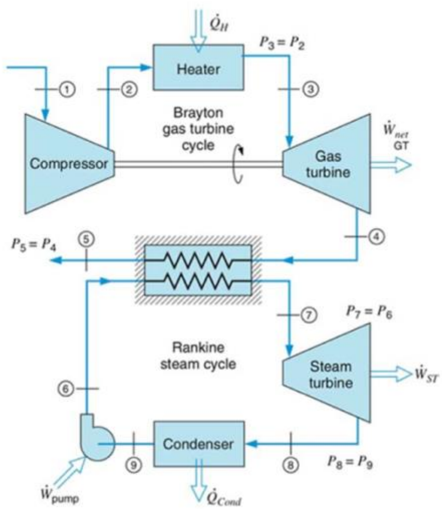

Figure 1-Basic CHP Cycle

While this configuration better helped me understand all the decisions that would go into this project, I wasn't overly fond of the simplicity. To solve this cycle I ended up writing a program in MATLAB that created one million(or more if desired) combinations of two unconstrained variables to determine which particular combination met all the constraints placed on the system while minimizing the amount of heat input into the cycle required. The results of this optimization problem, as well as the incomplete solution to the simple cycle will be included at the end of this document.

After I had a better understanding of the overall system, I decided to drastically increase the complexity of the cycle. I first drew the component diagram for the overall cycle that I wanted to consider, shown in Figure 2.

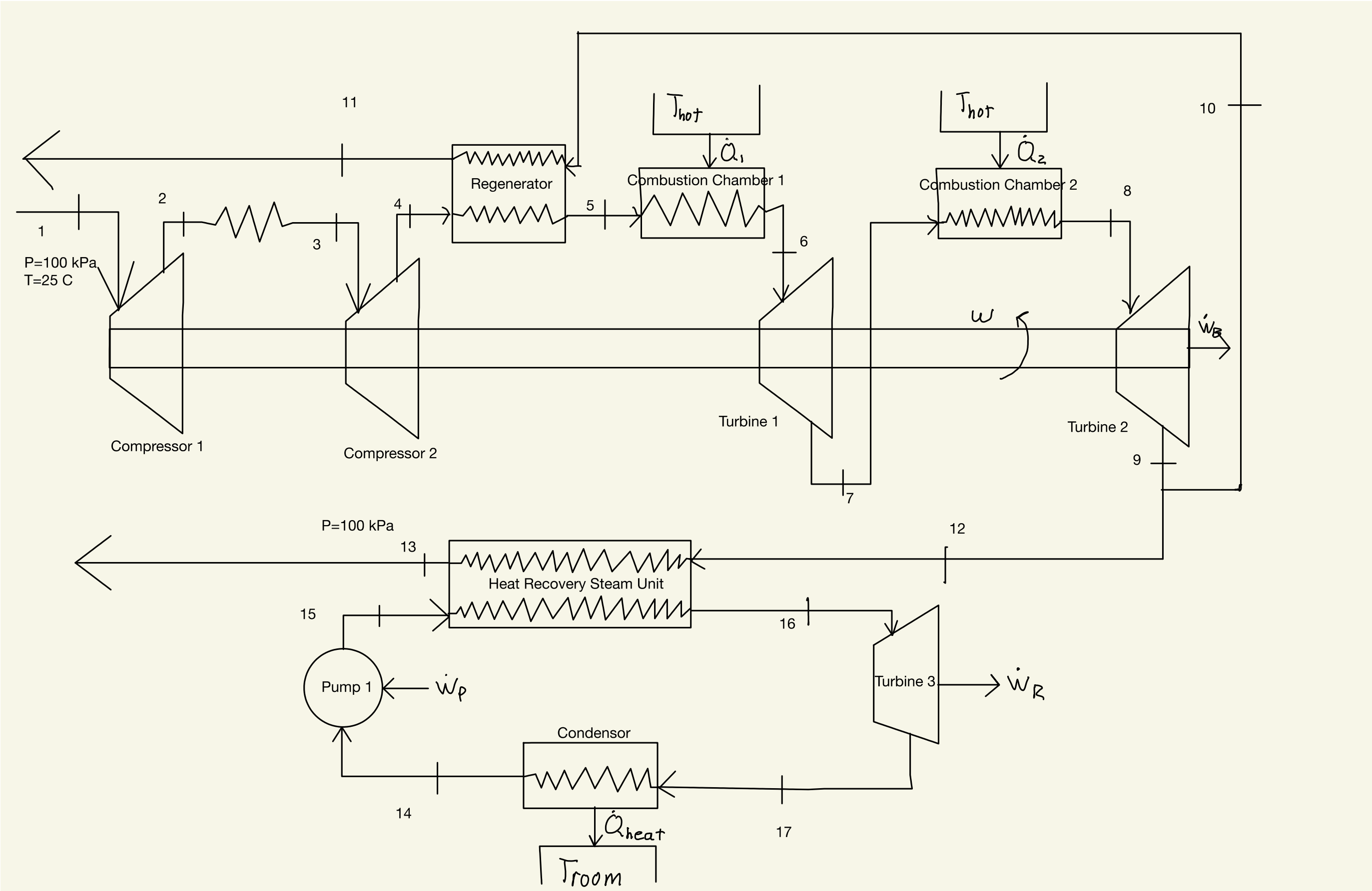

Figure 2-Overall Component Diagram

There are many more steps required to come to a final solution. Rather than showing each of these steps as Figures in this memo, I am including a copy of all the work I did to arrive at the solutions. This memo is mainly meant to demonstrate my decision-making process as I solved.

I chose this component diagram because after having solved the simple cycle, I found the majority of power production was done by the Brayton cycle. In light of this, I decided that if I were to attempt to increase the efficiency of any one cycle, the Brayton cycle would be where my time is best spent. In addition, being able to solve generally in the Brayton cycle allowed me to better understand the relationships between variables. This type of generalized solution is not possible for the Rankine cycle(at least not using water). I could have also added more components to the Rankine cycle to attempt to increase its efficiency, such as a closed-feed water heater or an open-feed water heater, but this seemed to really be going past the intended depth of this project.

Now that I had decided on a component diagram, I first solved the Brayton cycle generally using constant specific heats. Next, I started solving the Rankine cycle. The mass flow rate through the Rankine cycle as well as the minimum temperature through the condenser were constrained. This is because the condenser, where heat is rejected in the Rankine cycle, is what actually goes towards heating whichever facility is desired. This left the top half, states 15 and 16 in Figure 2, unconstrained. To fix these states, I considered a few potential methods and eventually decided to pick several reasonable pressure's and see what the temperature this implied state 16 would be at(I also had entropy at this state as I chose x=1 at state 17 with a known temperature at state 17 and an isentropic turbine). By setting the temperature at state 16 equal to the temperature at state 9(ideal heat recovery steam unit, variable m dot still available), I could then see what value of rP this implied for the Brayton cycle(I had to ensure rP was under 15). This immediately ruled out all but two pressure choices(that I had tables in the textbook for) for the Rankine cycle. Of these two pressures, one of them ended up implying a negative mass flow rate at state 10, so that one was thrown out. Thus, I arrived at the conclusion that the high-side pressure in the Rankine cycle was 30MPa.

Once this pressure was known, and thus all states in the Rankine cycle, with a known mass flow rate in the Rankine cycle, the entirety of the cycle became nothing but a computational problem. The results, using isentropic components, is as follows:

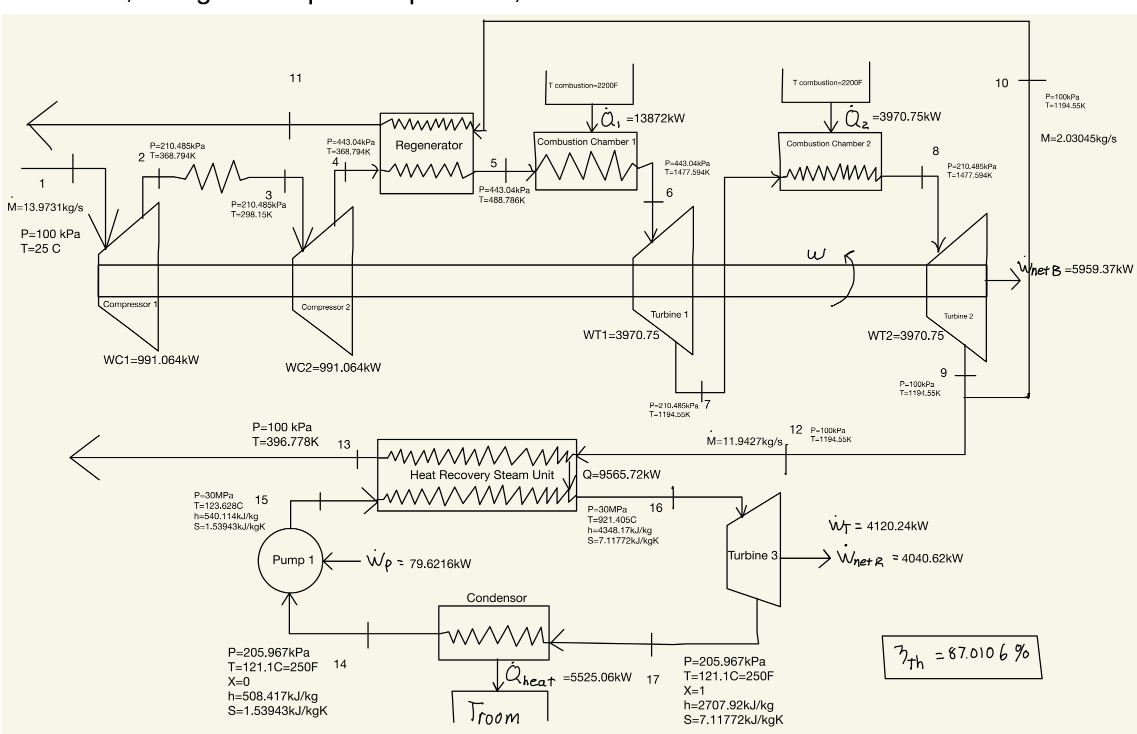

Figure 3-Solved Cycle using Isentropic Components

Next, I solved the cycle over again with actual components. I chose an efficiency of compression(both pump and compressors) of 85% and an efficiency of expansion(turbines) of 90%. I also chose a 90% efficiency for the regenerator and the heat recovery steam unit. These choices resulted in the following:

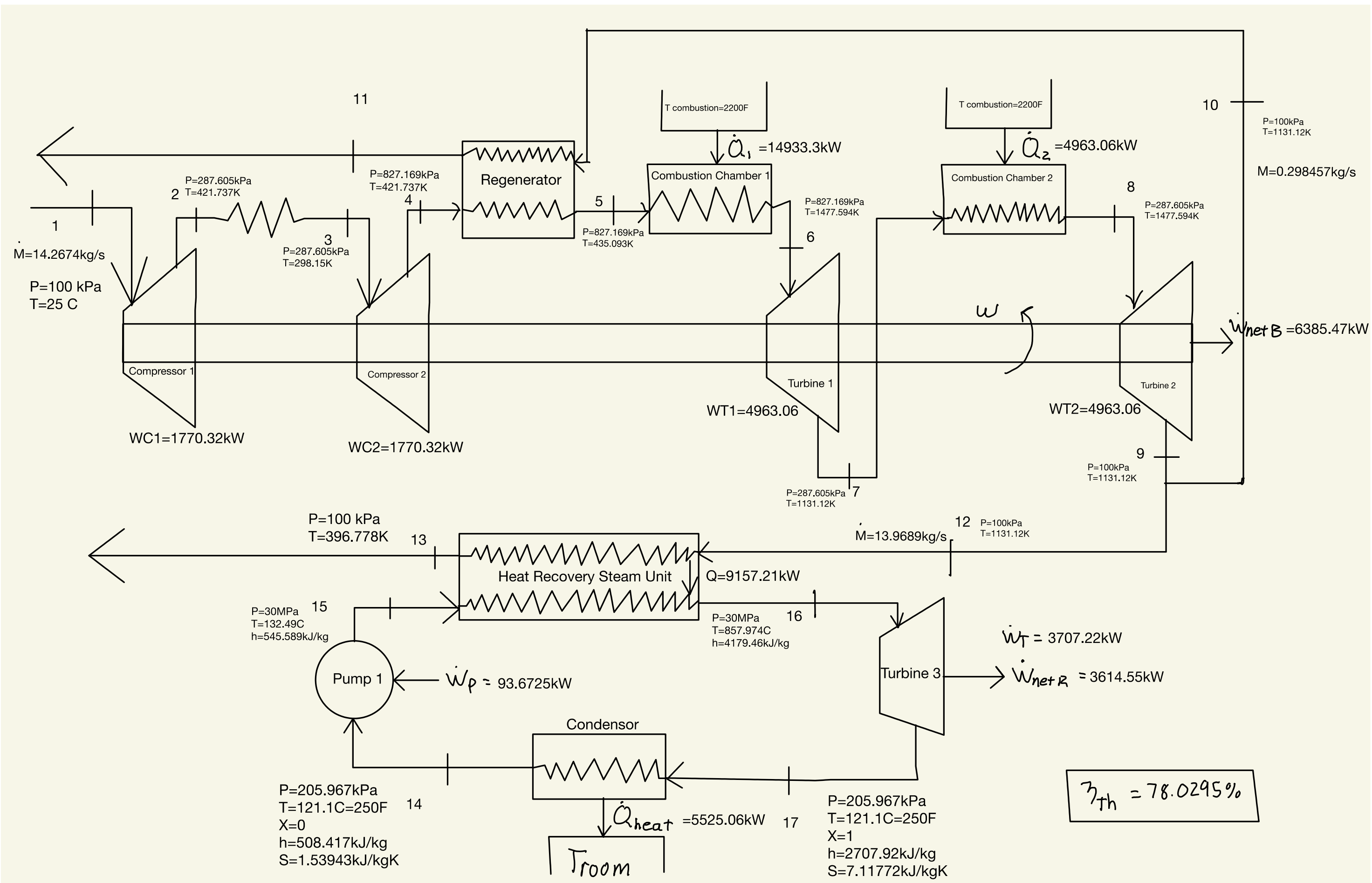

Figure 4-Solved Cycle using Actual Components

Once I had the cycle solved using both isentropic and actual components, I computed my cost to run each cycle for one day. To complete this computation, I assumed an energy density for natural gas of 37MJ/m^3,80% combustion efficiency, and a cost of \$4/1000ft^3. The results are as follows:

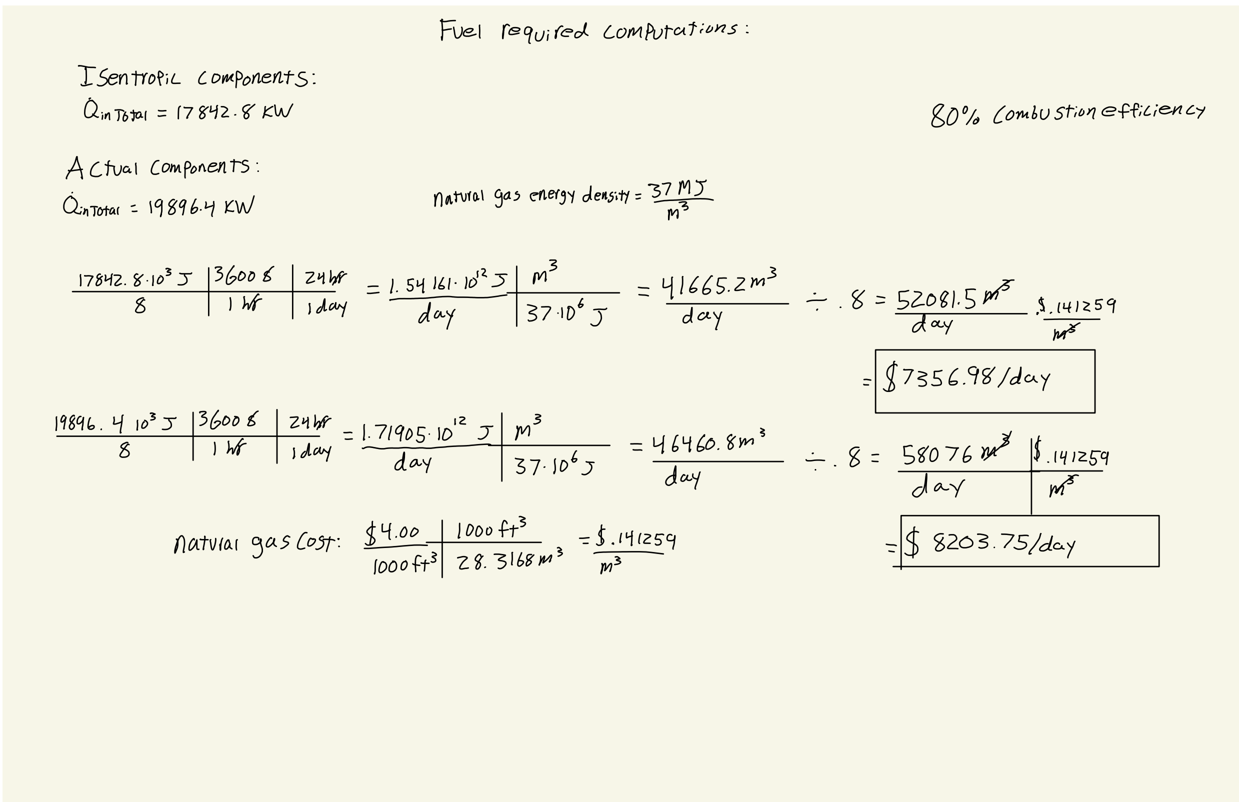

Figure 5-Cost in Dollars to Run Per Day