Rankine Cycle Project

MEMS 0051 - Introduction to Thermodynamics

Assigned: July 17^{th}, 2020
Due: August 5^{th}, 2020, 11:59 pm

Description

You have been tasked with maximizing the thermal efficiency of a proposed combined-cycle power plant composed of two cycles: a traditional steam driven Rankine Cycle and an R-134a driven Organic Rankine Cycle (ORC). The proposed design is shown in Fig. 1 below:

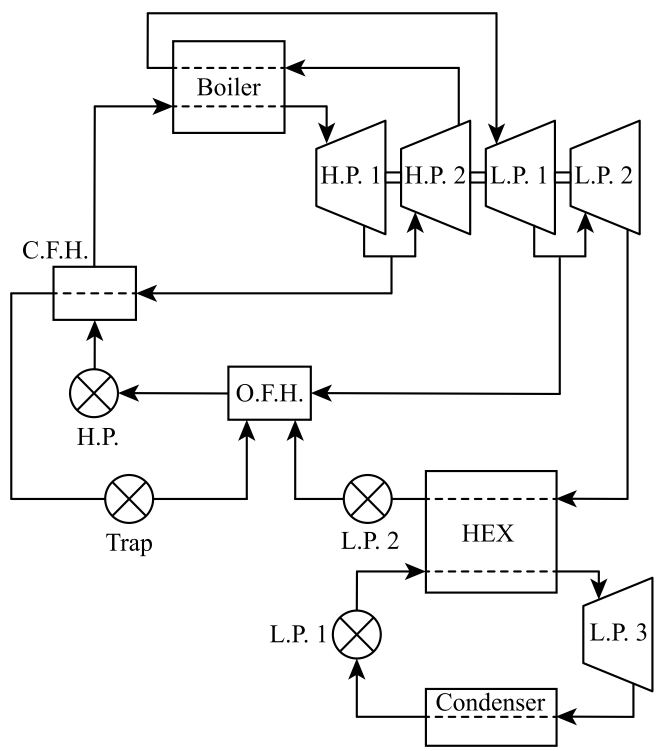

Figure 1: Combined cycle schematic.

The primary loop uses water as a working fluid. Steam enters a high-pressure turbine (H.P. 1) at an undetermined pressure and temperature. A portion of the working fluid is siphoned off before entering the second high-pressure turbine (H.P. 2) to a closed-feedwater heater (C.F.H.). The remaining steam is reheated before entering the first stage of a low-pressure turbine (L.P. 1). A portion of the working fluid is siphoned off and sent to an open-feedwater heater (O.F.H.) before entering the second stage of a low-pressure turbine (L.P. 2). The exhaust of L.P. 2 is sent to a heat exchanger (HEX), where thermal energy is transferred to a secondary working fluid. Upon exit of the HEX, the water is sent through a low-pressure pump (L.P. 2) before entering the O.F.H. The O.F.H. delivers the fluid to a high-pressure pump (H.P.), that then delivers the water to the

C.F.H. Upon exiting the C.F.H., the fluid enters the boiler.

The portion of fluid siphoned off between H.P. 1 and H.P. 2 transfers heat to the fluid exiting H.P. before it enters the boiler. Upon transferring said heat, the fluid exits the C.F.H. and goes through a trap before entering the O.F.H.

For the secondary loop, R-134a, a low-boiling point working fluid, is circulated through an ordinary Rankine cycle. The heat input is received from the HEX via the condensation of the primary working fluid. The heat is rejected to atmosphere via a condenser.

You are to specify the unknown State properties, as well as solve for all other pertinent State properties, of the system, in an effort to maximize the thermal efficiency of the combined cycle. Hint: utilize this.

Limits and Requirements

1. Maximum high-pressure turbine inlet conditions: $P = 25$ [MPa] $T = 600\,°\text{C}$;
2. Minimum turbine quality at outlet is 90%;
3. Reheat temperature may be equal to but cannot exceed maximum turbine inlet temperature;
4. Substances entering pumps must be a saturated liquid or a compressed/subcooled liquid;
5. The isentropic efficiency of the turbines is 85%;
6. The isentropic efficiency of the pumps is 60%;
7. Heat transfer in all heat exchangers/condensers requires a minimum of 15 °C temperature difference between working fluids. For example, if the water is condensing at 95 °C in the HEX, the maximum temperature of the fluid in the ORC is 80 °C,
8. The ambient temperature that the condenser is exposed to is 25 °C.

Technical Report

A brief report (in PDF format) and EES code that adequately summarizes your findings and results. The report should have the following:

a) Typesetting - the document is to be prepared in LaTeX. You can use a standalone compiler (TexMaker and MikTex), or an online compiler (Overleaf). A template can be found here.

b) Organization - the document should have the following sections:

   i) Title - the title should reflect the project in a creative, succinct manner.

   ii) Authors - each member should be identified, with corresponding email address. A corresponding author will be identified and shall be the point of contact.

   iii) Abstract - the abstract should contain all pertinent information. That is, you should convey to the reader what you have done, how you did it, and the significant findings, briefly. Although the abstract is to be concise, no more than 250 words, it should be coherent.

   iv) Nomenclature - a table with variables and symbols used within the analysis and presented within the document will be constructed. The variables and symbols will be identified, and include base SI units.

   v) Introduction - the introduction provides the reader with a historical background to the problem. Any previous theory or works should be cited (Harvard style is preferred). Care should be taken as to properly cite consulted works as to not plagiarize. The background should be long enough to pose the problem, yet concise enough to not bore the reader.

   vi) Methodology - the methodology section describes the equations used in EES, i.e. their formulation and assumptions. Superfluous equations shall be omitted, and equations used within the analysis shall be labeled and each term within shall be explained. A reader should be able to replicate your methodology, without ambiguity, and reproduce your results.

vii) Results and Discussion - the results and discussion section presents major findings of the analysis and testing. Pertinent figures, such as diagrams and schematics should be included within this section. Figures should be labeled and captioned.

viii) Conclusions - the conclusion is similar to the abstract in that it presents the significant findings of the project. The conclusion should include pertinent system properties were selected, and the maximum obtained efficiency. You must also fill out and sign and date the Group Member Contribution Form, which will be posted to Canvas.

c) Figures - figures should be of high quality (at least 600 dpi), have legible text (at least 10 point font), and when necessary, proper scales with units. Inkscape is a useful open-source software for schematics and figures.