Department of Mechanical and Aerospace Engineering,
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# Steam Power Plant Enquiry-Based Learning (EBL)[1]

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## 1. Introduction and Primary Objectives

Thermal power plants meet almost half of the world's power demand. Today's thermal power plants are capable to run under green efficiency by conforming to stringent environmental standards. The bulk of power plant capacity for electricity generation in the UK is based upon various refinements of the Rankine cycle. The **main purpose** of this activity is **a)** to understand the fundamental design and optimization process of steam power plants, and **b)** apply this knowledge to a (not too difficult) research problem!

### Part - A

Schematics of a simple **Rankine cycle** is shown in Figure 1. In such a cycle, a primary source of thermal energy (coal, oil, gas or nuclear) is used to heat water in a boiler, to produce steam, which is then expanded in a turbine to produce mechanical (shaft) work. The turbine shaft is connected to a generator to convert the mechanical work to the desired electrical output. After exiting the turbine, the steam enters a condenser which returns the working fluid to the liquid state. The cycle is completed by a feed pump which increases the working fluid pressure from condenser level to boiler level.

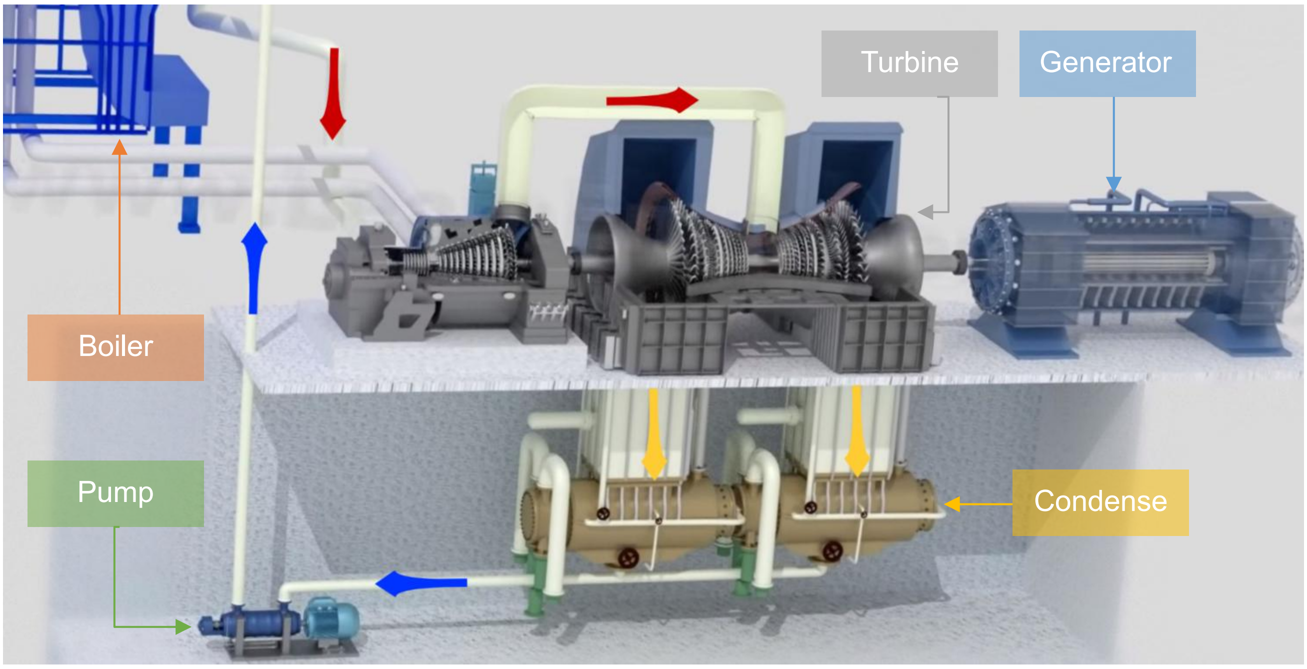


*Figure 1. Rankine cycle*[2]

A power plant working on a simple Rankine cycle would have a very low efficiency and a low capacity. They can be increased with a help of super heating, reheating and feed water heating. Hence, in this

[1] EBL simply means learning through doing.

[2] https://www.patreon.com/LearnEngineering

activity each group would work on developing, optimizing and evaluating two high efficiency steam power plants:

a) A superheated Rankine cycle with reheat
b) A superheated regenerative Rankine cycle with a single open feed water heater

## 2. EBL Instructions

**Two lab sessions** will be held in MECD. In the first one the steam cycle, its optimization and SPOWER software package will be demonstrated. The second one is Q&A and group progression check. More information regarding these sessions can be found in **appendix 1**.
Follow the instructions (Steps 1 to 5) to design, optimize and evaluate your steam power plant. Report writing guidelines and marking scheme are provided in **appendix 3**.

### Step 1. Research

EBL groups should research the following topics. Powerful referencing is very important in this part.

i. The simple superheated Rankine cycle
ii. The superheated Rankine cycle with reheat
iii. The superheated regenerative Rankine cycle with a single open feed water heater
iv. The gas-turbine cycle topping a simple superheated Rankine cycle
v. Isentropic efficiency
vi. Turbine design point performance
vii. Practical limits on plant operation

### Step 2. Design

Based on the findings in step 1 and practical limits on operating parameters, each group would develop their main designs for both reheat and regenerative cycles. All designs must take full account of irreversibility in plant components. In this step, appropriate justification for selected values is essential, which must include all the references. Just remember the Carnot theorem for the maximum efficiency possible.

### Step 3. Analysis[3]

The suggested designs in step 3 are analysed in terms of cycle efficiency and specific work output. The equations for different stages of both cycles, isentropic efficiencies and justification of the implemented values must be provided in this part.

### Step 4. Optimization and evaluation

In this stage, the design optimization and evaluation takes place. Since hand calculations for various design condition is time consuming, **SPOWER** is used for design optimization (only for types (ii) and (iii) above). SPOWER is available on Blackboard and instructions for use of the program will be provided in the demonstration session. Most of the mark in this section is dedicated to appropriate method for optimization, data analysis, and informative presentation of the results.

### Step 5. Finalizing the design

In the last stage, the **final best design** must be presented with a detailed discussion of its competitive

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[3] Note: Using Steam Tables and a calculator, a sample calculation should be undertaken for each of the designs (ii)-(iv) above. These should take account of irreversibility (see point (v) above) and established practical operating limits (point (vii)).

features including the operating conditions, materials, environmental aspects, long-term performance, other factors that influence the system performance, comparison with larger scales and conventional steam cycles. The conclusions should be based on the presented data and any appropriate external references, effect of your choice (feed water/reheat) on other parts in long term, etc. This is an important part and **25 marks** is dedicated to it.

## Part-B

Organic Rankine power cycles are becoming a leading technology for energy conversion, especially to convert low-temperature heat source. The use of an organic vapour in place of steam is very interesting for small/medium size power plants (50–5000 kW or more, at present). In the second part of this coursework, you are asked to write one-page document describing thermodynamics of Micro combined heat and power (CHP) plants operating through an organic Rankine cycle (ORC). This type of power plants are an improvement over the traditional Organic Rankine power cycles. To complete this exercise, students are encouraged to review the research paper titled: "*Thermodynamic analysis of two micro CHP systems operating with geothermal and solar energy*."

**This task contributes 5% of the total marks allocated to the EBL exercise**. Its purpose is to evaluate **a)** your ability to handle complex tasks and to comprehend and **b)** present complex information systematically. Your one-page report should not simply summarize the referenced research article. Instead, you should enhance the provided information by adding insightful analysis and interpretation.

## 3. Group Work Arrangements

There are **10 hours** allocated to this activity, which consists of the lab sessions, group meetings and member's activities as following.

- **2 hours.** Lab sessions with the tutors
    - Tutors will demonstrations the software and Q&A session (see appendix 1 for details).
- **1 hour.** Group meetings
    - Each group should nominate **a chair and minute-taker,** and hold at least **four formal** meetings with agendas, minutes and list of attendees, and provided in the appendix of the final report.
    - The group chair is responsible for coordinating the meetings and any communications between the team members. The email address of all the members are provided in Appendix 2.
    - At the **first meeting**, group members divide the activities and make a plan. The next group meetings would be dedicated to check the progress and determine further works.
- **7 hours.** Each group member
    - Each group member should spend seven hours on researching his/her allocated task, and writing up the section of work for the final Group Report.
    - All members of a group should become proficient in the use of SPOWER

These 10 hours constitutes 20% of the unit for TPFE MSc Thermodynamics. Each group is required to produce a report, which should include details of the preliminary steam tables calculations and the larger-scale SPOWER optimisation exercise. Check the writing guidelines provided in the **Student Study Essentials** on Blackboard to right a high-quality report.

The final time should be spent ensuring that the consistency of the report, its format (see appendix 3 for more information) and making sure all the requirements are met.

## 4. Report Submission (*Please read carefully*)

- **Deadline** for report submission: **5pm, Friday 2 May 2025.**
- The **group chair** is responsible for uploading and submitting the report via blackboard.
- **Late report submission** will lead to the award of reduced marks for the report for the entire group, as prescribed in the University guidelines.
- **One report per group** – the mark for this constitutes 90% of the total mark for the EBL activity (report submission guidelines are below). All members of the group must sign their names on the front cover of the report.
- The report is to include the **agendas and minutes** of all meetings – the mark for this constitutes 10% of the total mark for the EBL activity. Note that these minutes may be used to assess individual student's participation in the EBL activity.
- **Group contribution** must be equal and all members are expected to fully engage and contribute. Lack of attendance in meetings, failure to contribute to the analysis and the report, etc must be reported to the tutors in advance of the submission and these must be recorded as part of the appendix. Any members with clear lack of contribution will be penalised and their individual mark could be significantly lower that the rest of the group. However, please note it is the responsibility of the team members to ensure effective communications in meetings, allocating tasks, following up on actions and providing a fair and friendly environment for everyone to contribute towards the final report.

# 5. Appendices

- Appendix 1 - EBL Group Demonstration Timetables
- Appendix 2 - EBL Group Allocations
- Appendix 3 - Report Writing Guidelines
- Appendix 4 - Instructions to load software

## Appendix 1 - EBL Groups Demonstration Timetables

**Activity1:** SPOWER Demonstrations
**Date: 3** March 2025
**Time:** 15:00-16:00
**Location:** George Begg Bld (B7 Computer room)
The demonstrations of the use of SPOWER will be held in person in a computer room in MECD. Following the demonstration sessions, the group members should start working amongst themselves on the activities that have been described above. The group demonstrators will be reachable via email during the entire course of this activity and will assist groups with the use of SPOWER.

| ***Tutor*** | ***Groups*** | | | | |
|---|---|---|---|---|---|
| *Dae Yeob Lee* | 1 | 2 | 3 | 4 | 5 |
| *Sumanta Laha* | 6 | 7 | 8 | 9 | 10 |
| *Yihe Yu* | 11 | 12 | 13 | 14 | 15 |

**Activity2:** SPOWER Individual Group Q&A Session
**Date:** 24 Apr 2025
**Time:** 15:00-16:00
**Location:** George Begg Bld (B7 Computer room)
This session will be split into 20-minute sessions, with each group having one-on-one time with a demonstrator, where the demonstrator will assess the groups on their capability of using ‘SPOWER’ and their knowledge on steam power plants. All members of the group are expected to be proficient in the use of SPOWER and to answer detailed questions on steam power plant.

| ***Session Time*** | ***15:00-15:12*** | ***15:12-15:24*** | ***15:24-15:36*** | ***15:36-15:48*** | ***15:48-16:00*** |
|---|---|---|---|---|---|
| *Dae Yeob Lee* | 1 | 2 | 3 | 4 | 5 |
| *Sumanta Laha* | 6 | 7 | 8 | 9 | 10 |
| *Yihe Yu* | 11 | 12 | 13 | 14 | 15 |

**Tutors**
The following teaching assistants are available to assist with the use of SPOWER and provide general back-up on steam power plant. Their email address are shown below for further information.

| ***Tutor*** | ***Email Address*** |
|---|---|
| *Dae Yeob Lee* | daeyeob.lee@manchester.ac.uk |
| *Sumanta Laha* | sumanta.laha@manchester.ac.uk |
| *Yihe Yu* | yihe.yu@postgrad.manchester.ac.uk |

## Appendix 2 - EBL Group Allocation

See blackboard for group allocations

## Appendix 3 - Report Writing Guidelines

**Reports should not exceed more than 20 pages in length (this excludes the cover page and Appendices)**

*The reports should consist of the following sections marked clearly in bold letters in a sequential order listed below,*

1. **Abstract** *(should provide the aims and the overview of the work which has been carried out).*
2. **Introduction** *(should provide a brief summary of the research undertaken for the topics mentioned on EBL handout).* [5 marks]
3. **Practical limits on plant operation** *(turbine inlet temperature/condenser pressure and temperature/dryness fraction at exit from the low pressure turbine)* [10 marks]
4. **Definition of isentropic efficiency and typical values** *(should include the appropriate justification for the selection of values)* [10 marks]
5. **Turbine Analysis** *(outline the process of estimating the design point performance and the isentropic efficiency of the turbine)* [5 marks]
6. **Analysis ('on paper') of the reheat cycle** *(include the appropriate justification for the inlet values that have been undertaken for the calculations, including isentropic efficiencies, and the equations used in calculations).* [5 marks]
7. **Analysis ('on paper') of the regenerative cycle** *(include the appropriate justification for the inlet values that have been undertaken for the calculation, including isentropic efficiencies, and the equations used in calculations).* [5 marks]
8. **Effect of varying plant operating parameters on thermal efficiency and specific work output** *(computational exercise, attach the SPOWER calculations as tables in the appendix and refer to them for appropriate justifications)*
   Note: The computational exercise refers only to reheat and regenerative [20 marks]
9. **Final optimised designs** for both systems *(refer to SPOWER tables attached in appendix for appropriate justifications).* [5 marks]
10. **Recommendations** of favoured design (reheat or regenerative). [15 marks]
11. **One page report on Part-B** [10 marks]
12. **List of references**
13. **Appendix**
    *(Appendix A should include SPOWER Tables)* [5 marks]
    *(Appendix B should include agenda and minutes of meetings)* [5 marks]

## Appendix 4 - Instructions to load software

Please follow this link for advice on how to download ‘MATLAB’ as it is required software for the course work (License is provided for all UoM Students):
https://research-it.manchester.ac.uk/news/2020/09/22/matlab-licence-update-sept2020/

- Install Matlab on PC (see link above)
- Open MATLAB
- Download SPOWER Files from Blackboard
    - MECH63081 Thermodynamics
    - “Course Context”
    - “Coursework: MATLAB”
    - Download ZIP Folder “Program files”
    - Extract all and save on your PC
- Navigate to the SPOWER Files folder “Program files” and open Main.m
- Press the run button 
- When asked, press “change folder”
- All outputs are saved in Excel files in the “Program Files” folder. After different values are entered and calculated they will update the excel sheet, responding to the cycle, automatically