ENGR 222 Bonus Project
<u>Design and Optimize a Power Plant</u>

Problem Statement:
A steam power plant is being built to power a city. It is determined the city has power needs of 25 MW. The city has hired your engineering firm to construct this power plant. Your firm has identified the following vendors for system components. The company uses a piping system from a sole vendor provider. Design the best system possible for the city that satisfies the city's power demands while utilizing the least amount of water (as determined by mass flow rate), minimizing the fuel consumption rate within the power plant, and minimizing overall piping length in the power plant. In your write-up, two system configurations (your chosen system plus one alternative configuration) must be considered and compared. A system configuration includes a pump/compressor, boiler, heat source, and turbine. An alternative system configuration must have a different pump/compressor, boiler, and turbine. All teams must be composed of students in the same section of Thermodynamics.

For this project, your goal is to minimize the Hollins-Reis (HR) constant, developed by Drs. Hollins and Reis at LA Tech. This constant is a scalar measure of an engineering design's negative impact on the environment, expressed as a relationship between resource consumption (water and fuel) and environmental pollution (in the form of pipeline construction). A larger Hollins-Reis constant indicates a more significant negative impact on the environment. The function for the Hollins-Reis constant is shown below:

$$HR = 5.1A + 8.8B + 2.1C$$

Where A is the magnitude of the mass flow rate of water through a power plant in kg/s, B is the magnitude of the rate of fuel consumption in a power plant in kg/s, and C is the magnitude of the length of pipelines laid externally to the power plant (the exit pipe from the turbine to the river) in m.

Considerations:

- Water is collected from a river, run through the steam power plant to produce power, and then released into the river downstream.
- The average annual temperature of the river is 20 °C, and the absolute pressure of the river is 100 kPa.
- The Environmental Protection Agency (EPA) requires the temperature of the water returning to the river must not be greater than 7°C than the average annual temperature of the river.
- The boiler is connected to the pump/compressor by a pipe with a length of 50 meters.
- The turbine is connected to the boiler by a pipe with a length of 40 meters.
- Pressure losses in ducts/pipes between turbomachinery (inside the power plant) must be accounted for in the design, occurring at a rate of -5 kPa/m of pipe length.
- The piping inside the power plant (from pump/compressor to turbine) has heat losses that total 3% of the entering enthalpy between power plant components. For example, if the water has an enthalpy of 100 kJ/kg leaving the pump, it enters the boiler with an enthalpy of 97 kJ/kg.
- The piping leaving the turbine is not insulated, losing heat at a rate of 500 W/m of pipe length.
- You are not required to operate the turbomachinery at the upper limits of operation, but you cannot exceed the upper limit of operation for any piece of machinery.
- Assume negligible changes in kinetic energy and potential energy as the working fluid travels through the pipes.
- Assume the boiler is isobaric, the turbine is adiabatic, and the pump/compressor is adiabatic.

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Shown in Table 1 are the available turbines for purchase, along with the equipment specifications.

Table 1: Available Turbines

VENDOR	PRESSURE LIMIT	TEMPERATURE LIMIT	ISENTROPIC EFFICIENCY
XYZ Thermal Installers, Inc	16 MPa	600 °C	82%
Shadow Power, LLC	17.25 MPa	525 °C	87%
Higher Heat, Inc	15.5 MPa	625 °C	74%

Shown in Table 2 are the available pumps and compressors for purchase, along with the equipment specifications.

Table 2: Available Pump/Compressors

VENDOR	TURBOMACHINERY	PRESSURE LIMIT	ISENTROPIC EFFICIENCY
XYZ Thermal Installers, Inc	Pump	18 MPa	86%
Shadow Power, LLC	Compressor	20 MPa	93%
Tighter Water, LLC	Pump	15 MPa	89%
Higher Heat, Inc	Pump	16 MPa	97%
Compressed Incompressibles, Inc	Pump	17 MPa	88%
Close Air, Inc	Compressor	19 MPa	91%

Shown in Table 3 are the available fuel sources for use along with the fuel's lower heating value.

Table 3: Available Fuel Sources

FUEL SOURCE	HEATING VALUE
Coal	32,800 kJ/kg
Natural Gas	45,000 kJ/kg
Gasoline	44,000 kJ/kg

Shown below in Table 4 are the available boilers for purchase, along with the boiler efficiency. The boiler efficiency measures how well it converts the fuel source into useable heat.

Table 4: Available Boilers

VENDOR	FUEL SOURCE	EFFICIENCY
XYZ Thermal Installers, Inc	Coal	89%
	Natural Gas	78%
	Gasoline	72%
Shadow Power, LLC	Coal	88%
	Natural Gas	77%
	Gasoline	74%
Higher Heat, Inc	Coal	90%
	Natural Gas	81%
	Gasoline	76%

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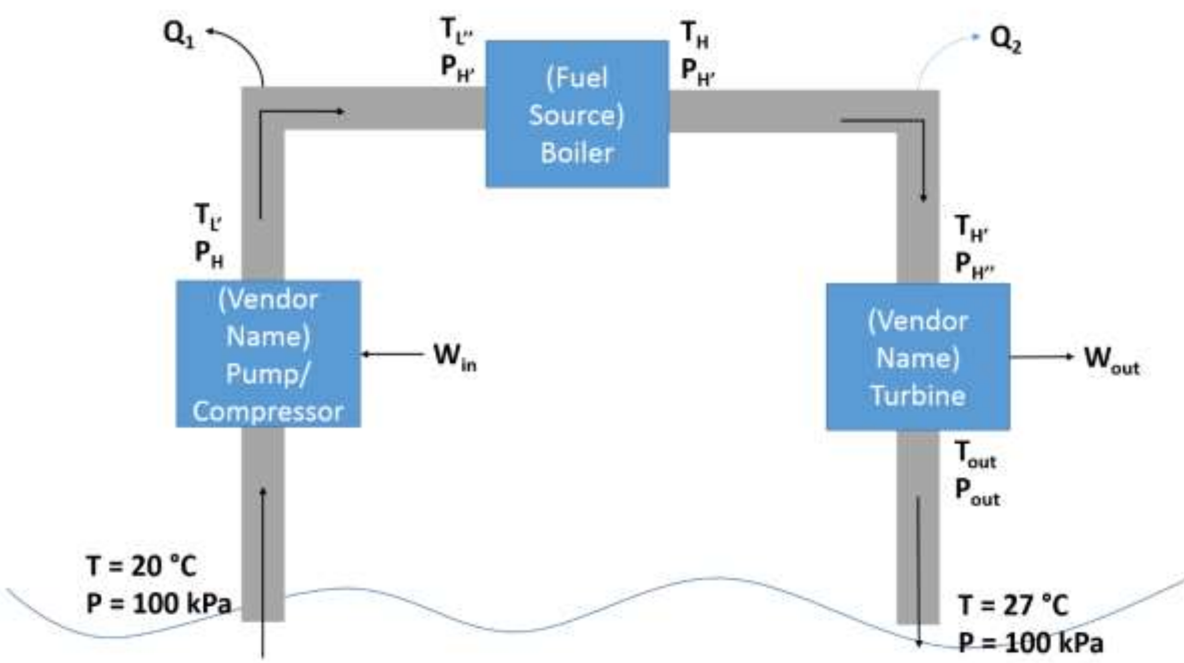
Project Write-Up:

For the project write-up, the following elements are expected.

1. A small abstract of your chosen design, including important factors like mass flow rate, rate of fuel consumption, operating conditions of the turbomachinery, and your calculated HR constant. The abstract should not exceed 250 words.
2. A detailed description of your chosen design and your alternative design considered
    a. For data presentation, include tables that show important values. Tables must stand alone but be referenced and explained in the text. Please do not include a table without any in-text citation or explanation of its purpose in the text.
    b. Include the following figure in your write-up, and include, in a table format, the values you used for the variables on the figure for each design considered. You must replace statements in parenthesis, like (fuel source), with the actual item you used. For example, the (fuel source) Boiler box should read Gasoline Boiler if you used gasoline as your fuel source. Fully define all the states within your system, including enthalpy values.



    c. The HR constant for each design must be included in the report write-up.
    d. For all calculated values presented in the write-up, a reference to the calculation to get that value in the Appendix (Appendix page number) must be provided.
3. Include a brief, high-quality discussion (no more than two paragraphs) about the long-term implications of your design. Consider discussing things like turbomachinery longevity, economic factors for the implementation of your chosen design, etc.
4. The write-up must be concise, <u>not exceeding six pages total</u> (including abstract, but excluding Appendix).

5. Calculations may be made using a computer program, such as MathCAD or Excel. Using these programs (particularly Excel), the cells containing formula calculations should be highlighted, and the formulas themselves should be included in the report. An example is shown below. If using MathCAD, number your equations on the sheet for easier reference.

Data Table					
Object	Mass, kg	Height, m	Velocity, m/s	Potential Energy (kJ)	Kinetic Energy (kJ)
Element 1	1200	15	22.7	176.58	309.17

All cells shaded yellow calculate the following equation: $PE = m * g * h$

All cells shaded blue calculate the following equation: $KE = m * (\frac{V^2}{2})$

6. For equations included in the document's text, use Microsoft Word's Equation Editor.
7. All calculations made during the project must be included in an appendix to the report. There is no page limit to the number of calculations included in the Appendix. Do not use the Appendix to circumvent page limitations of the write-up.
8. A project scoring bonus will be provided to the team that satisfies the project's requirements with the lowest Hollins-Reis constant.