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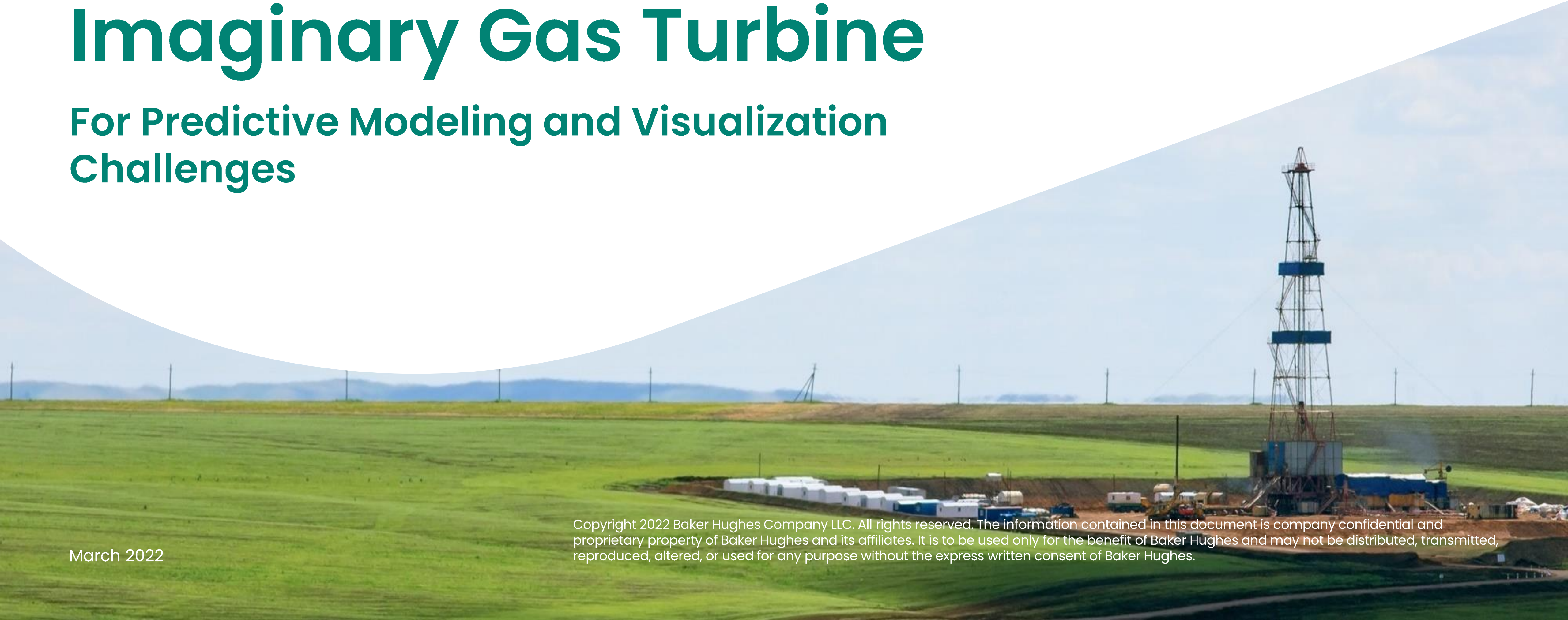
Introduction to an Imaginary Gas Turbine

For Predictive Modeling and Visualization Challenges



March 2022

Overview

In the challenge, you will deal with a synthetic fleet of gas turbines. This material will help you understand the data.

Also, this is not a thermo lecture, but thermodynamics background will be useful for those who want to go deeper on understanding this material.

Don't get too bogged into details here. **It's not necessary to be an expert in gas turbines to solve the challenges!** However, if you feel curious and want to understand better the problem, the data generation process and have useful ideas for your challenge, you've come to the right place!

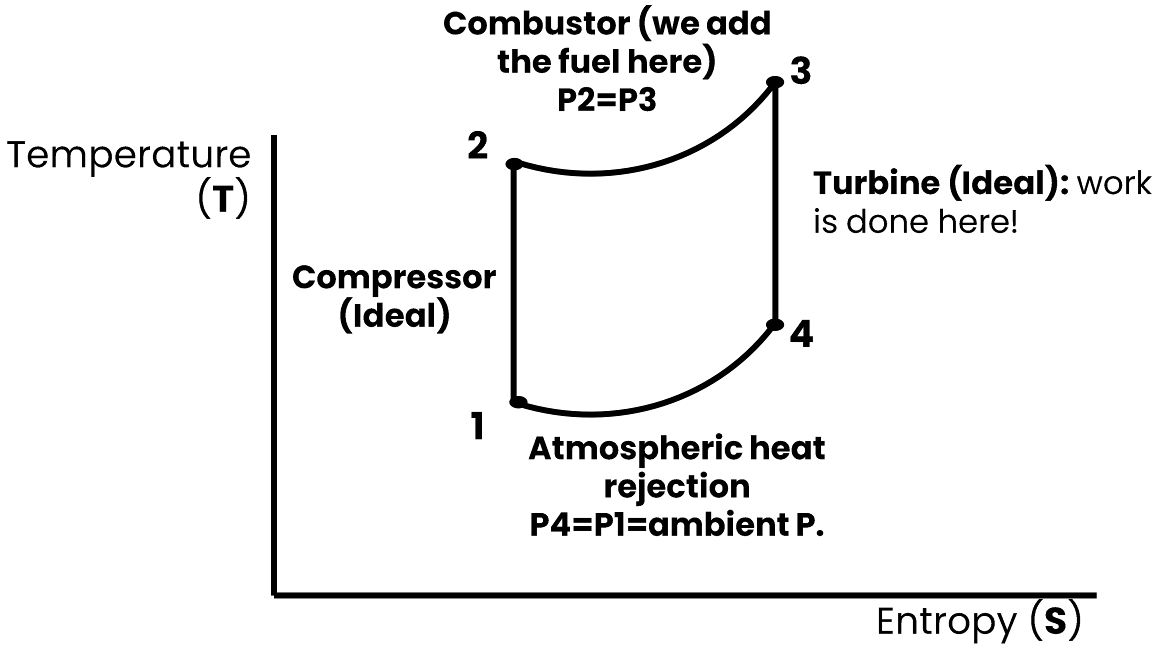
Note that the data in the challenge does not reflect any Baker Hughes product and is not comparable to any of our gas turbines. The data was obtained as a result from an extremely simplified simulation and under assumptions that would normally not hold with real data.

None of the data is real. Site coordinates, customer and plant names were synthetically generated.

Brayton Cycle

The Brayton Cycle is often used to model the gas turbine. The Brayton Cycle consists of four processes:

- Isentropic compression (constant entropy)
- Heat addition at constant pressure
- Isentropic expansion (constant entropy)
- Heat rejection at constant pressure



More on P-V and T-S diagrams:
https://www.grc.nasa.gov/www/k-12/airplane/pvtsplot.html

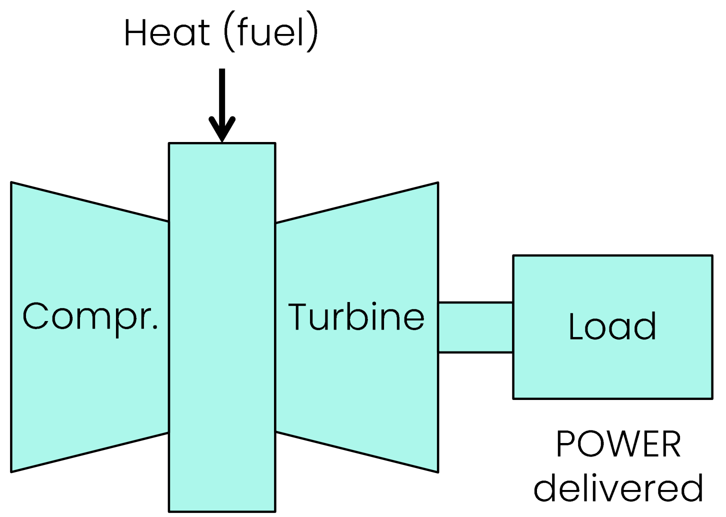
More on entropy:
https://www.grc.nasa.gov/www/k-12/airplane/entropy.html

More on the Brayton Cycle:
https://www.grc.nasa.gov/www/k-12/airplane/brayton.html

Brayton Cycle

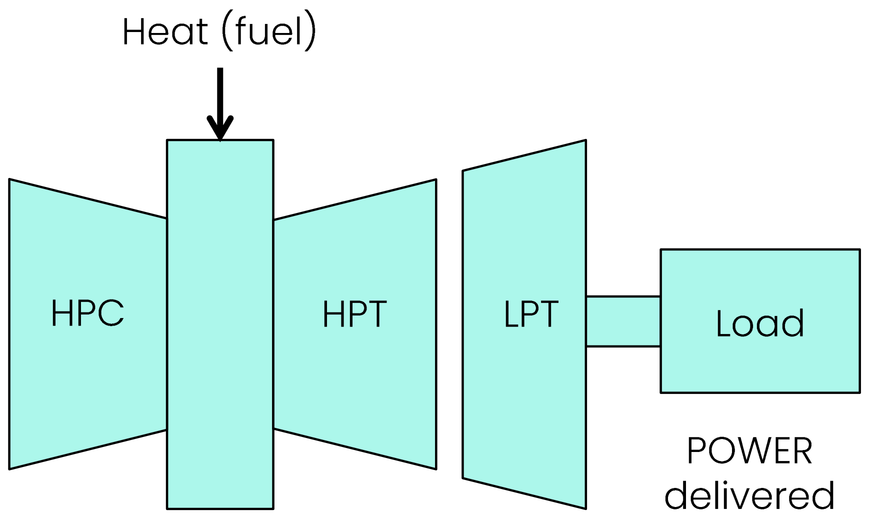
In the Brayton Cycle, each process corresponds to a physical component, namely a compressor, which compresses air for the combustion, a combustor where fuel is added and expels heat, and a turbine where the hot gases expand and generate useful work.

A Brayton Cycle simulates a single shaft gas turbine:



But the Gas Turbine for the challenge (a 1 ½ shaft gas turbine) is like this:

1 ½ shaft = one shaft with compressor and turbine and another shaft just with the power turbine



(*) HPC = high pressure compressor, HPT=High Pressure Turbine, LPT = Low Pressure Turbine OR also called power turbine

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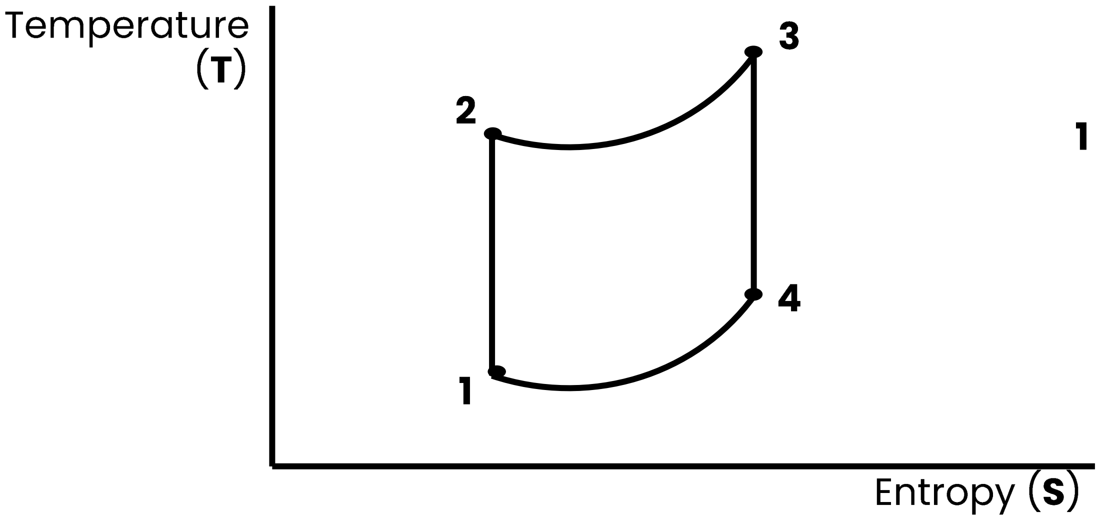
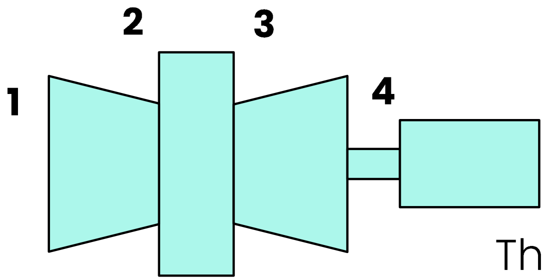
Single Shaft vs. 1 ½ Shaft Diagram

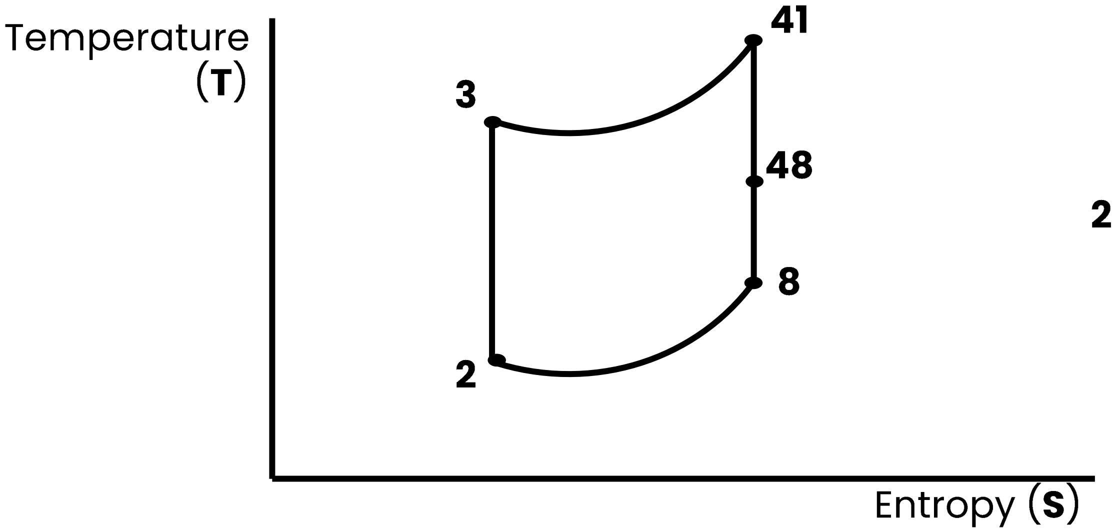


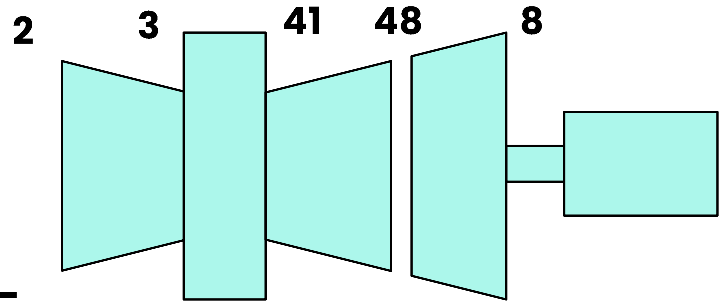


Single Shaft

The Brayton cycle, or single shaft gas turbine, can be represented ideally with the thermodynamic cycle in the top of the page.

The 1 ½ shaft gas turbine would be better represented with the cycle in the bottom of the page.





1 ½ Shaft

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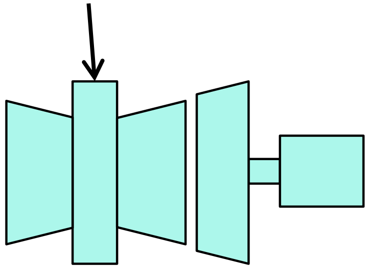
How does the engine work? How does the fuel convert into power?

STEPS TO GENERATE POWER WITH A 1 ½ SHAFT GAS TURBINE

1

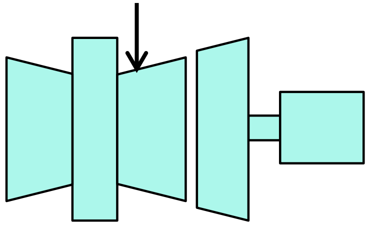
Input fuel flow



ROTOR IS SPINNING

2

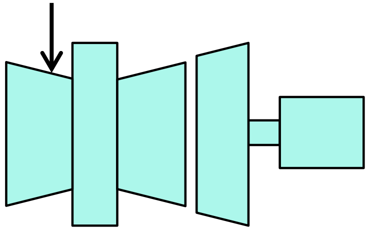
Air temperature in the combustor increases!



Gases in the HPT have more energy, and the ROTOR ACCELERATES

3

Comp. discharge temperature and pressure increase!

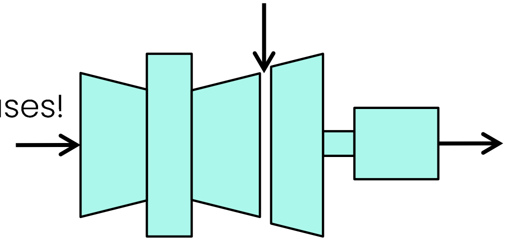


Since the compressor spins faster, the mass through the compressor increases!

4

Power Turbine Temperature increases

Mass increases!

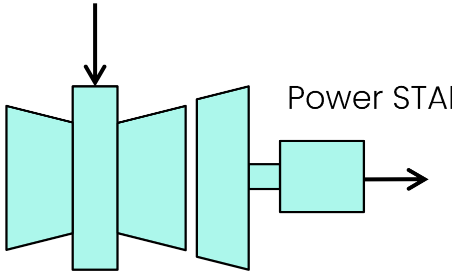


Power increases!

Increasing the power turbine temperature means that there is more Energy available in the power turbine.
More mass in the engine means more energy as well

5

Regulate fuel flow until power stabilizes at setpoint



Power STABILIZES!

ROTOR SPINNING FASTER THAN BEFORE

VERY IMPORTANT:

Note that, as you input more fuel, the speed of the compressor rotor (also called the Gas Generator, or the HP Rotor) spins faster.

Also, the internal temperatures and pressures increase. This cannot go on forever. The engine could break!

For the Hackathon, this imaginary engine can only go to a maximum speed of 10000 RPM. This is considered the maximum power that the engine can provide at current ambient conditions.

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More Information about Gas Turbines

If you want to go deeper on the Gas Turbines, check the following links:

- On Compressors: https://www.grc.nasa.gov/www/k-12/airplane/compress.html
- Combustor: https://www.grc.nasa.gov/www/k-12/airplane/burner.html
- Power Turbine: https://www.grc.nasa.gov/www/k-12/airplane/powturb.html

General overview on Propulsion with Gas Turbines:

- https://www.grc.nasa.gov/WWW/K-12/airplane/bgp.html

Good luck! Hopefully, we have made you curious about Gas Turbines ☺

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