Brayton Cycles: Steam plant field trip, literature searches related to project [MECH 251] April 25.

When you woke up this morning & flipped on your coffee pot or hopped in the shower, did you think about the ramifications of you or other people doing the exact same thing at the same time?

Power Demand

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>6am</td>
<td>Wake up and start showers</td>
</tr>
<tr>
<td>Noon</td>
<td>Everyone at work. House running</td>
</tr>
<tr>
<td>4pm</td>
<td>Everyone doing homework</td>
</tr>
<tr>
<td>8pm</td>
<td>Everyone turns on plasma TVs to watch Survivor</td>
</tr>
</tbody>
</table>

Midnight 8am 12pm 4pm 8pm Midnight

Baseline provided by big nuclear, hydroelectric, coal etc, using Rankine cycle. 8am-2pm & are very expensive.

You can't afford to build a Rankine cycle to meet the peak load & only use it 50% of the time. We still don't have good ways to store energy efficiently.

To meet this peak demand in this country we use almost entirely natural gas fueled peaking plants that operate using the Brayton cycle. Brayton cycles can be open (air) or closed (helium, argon etc.) usually they operate with air because it is free & abundant.
Brayton Cycle:

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Ambient (1) → Compressor (2) → Fuel  → Combustor (3) → Power Turbine (4) → Exhaust (5) to Ambient
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Processes:
1 → 2 Compression
2 → 3 Heat addition via combustion
3 → 4 Gasifier-turbine expansion
4 → 5 Power turbine expansion
5 → 1 Air exchanges heat with surroundings until equilibrated

We haven't studied combustion yet, form:
1) Energy per mass of fuel provided by combustion is given by the heat of combustion, \( q_c \).
2) Combustion products can be treated as air.

Definitions for Gas Power Cycles:

- \( P_R = \text{Pressure Ratio} = \frac{p_2}{p_1} \)
- \( BWR = \text{Backwork ratio} = \frac{W_{\text{comp}}}{W_{\text{GT}} + W_{\text{Pt}}} \)
- \( AT = \text{Air Fuel Ratio} = \frac{\text{mass flow of air}}{\text{mass flow of fuel}} \)

Wait a minute... how come we have extra power leftover? Cycle swept out an area, \( W = \int PdV \) → \( \frac{\dot{W}}{\dot{m}} = \int \frac{\dot{m}P}{V} \) is much larger at the turbine.

So, if \( AT \) is required to do the same work, \( AT \) must be increased.

Which thing takes less work to compress? Liquid or vapor?

Vapor takes a lot of work to compress, so typical Brayton cycle efficiencies are around 30%.

*Typical Brayton Cycle Efficiency: 30% → 50%*
Advantages of Gas Turbine Engine/Brayton Cycle:

1. Huge power to weight ratio; typical car engine = 750 BHP/pitcair 150 hp
   \[
   \text{Car Power} = 750 \text{ BHP} = 0.2 \text{ HP/} \text{lb}
   \]
   \[
   \text{Typical gas turbine engine used in a helicopter.}
   \]

  \[
   \text{helicopter GTE Power} = \frac{400 \text{ HP}}{400 \text{ hp}} = \frac{3}{1} \text{ HP} = 15 \times \text{ Power to weight versus car!!}
   \]

2. This is why GTEs are used on fighter jets, airplanes, & spacecraft. Low mass = low cost. No huge heat exchangers made of highly conductive material.

3. They aren't used because of \[ T \text{ Thermal} \] which is actually worse than most.

Why such a high power to weight ratio?

1. No HEX's (condenser or boiler) which are usually the largest component.

2. Higher linear speeds are possible versus ICE's
   - Not intermittent but continuous operation
   - Velocities of turbine tips approaches Mach 1
   - ICE's can't come closer, acceleration & deceleration would kill it.
   - You can therefore process far more air.
Energy Storage: Chemical: hydrogen, diesel, ...
Thermal: Molten salt, steam, water, ice
Mechanical: Spring, APE, KE
Electrical: Superconducting magnet coil, batteries
Nuclear: antimatter, enriched fuels, uranium, etc.