High-Efficiency Power Generation: A Fuel Cell/Internal Combustion Engine Combined Cycle

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**MOTIVATION**

Fossil Fuels as an Energy Resource

- In 2011, fossil fuels accounted for over 80% of the world's energy resources.
- It is necessary to find ways to use fossil fuels efficiently and in ways that reduce environmentally harmful emissions.

Using Fossil Fuels Efficiently

- Piston engines are widely-used energy conversion devices that use fossil fuels. Their efficiencies typically do not exceed 45%, regardless of whether they are naturally-aspirated or turbocharged.
- ~20% of the available exergy is destroyed due to the combustion process.
- PROJECT GOAL: reduce exergy destruction due to combustion by constructing a combined cycle where part of the fuel conversion process occurs as restrained reactions in a fuel cell.

**SYSTEM CONCEPT**

- Cylinders 2 and 4 act as afterburners and combust any species that have not been fully oxidized by either the fuel cell or cylinders 1 and 3.
- Cylinders 1 and 3 act as fuel reformers and run rich, resulting in a product stream of approximately 5-10% H₂ and 10-15% CO.
- The stream, which now contains a large amount of H₂, goes through the fuel cell, but not all of the H₂ is utilized.
- Rich combustion products undergo the water gas shift (WGS) reaction, resulting in a product stream of 20-25% H₂ and 0.25-3% CO.

**RESULTS**

Engine/Shift Reactor Product Stream

- Reasonable levels of H₂/CO can be achieved using an SI engine and shift reactor with both iso-octane and methanol as the cycle input fuel.
- When using iso-octane, the engine would need to run below an equivalence ratio of 1.6 to avoid soot formation.

Expected Fuel Cell Performance

- Supplier-provided data shows that even with 1% CO (which is achievable using an SI engine + shift reactor) fuel cell does not undergo significant performance drop.