

mae 432 2009 DESIGN PROBLEM

The company by which you are employed manufactures electric power industry equipment. Your boss has read the attached Forbes article and has become concerned about the implications that can be drawn from the article. Your boss is not impressed by the quoted 35% efficiency.

On further consideration your boss sees that there might be an opportunity in this cycle. Can the efficiency of this cycle be improved and used to isolate carbon dioxide and sequester it in exhausted oil wells or salt domes? For a 100 MW plants develop the most efficiency cycle you can given the following constraints. Plant efficiency will be increased by your improvements to the process. However a portion of the plant output must be used to operate the oxygen plant and some portion must be used to compress the resulting carbon dioxide for sequestration. What is the net (Work = plant output – oxygen plant power – sequestration compression) efficiency? How does this compare to the 55 to 60% efficiency that can be obtained in a combined Brayton-Rankine cycle. Write a professional report of the quality you would submit to an employer or client summarizing the improved cycle and compression designs you have specified and their performance. Support your design choices with calculations. Develop and report your opinion of the potential for success of the sequestration process.

Assume:

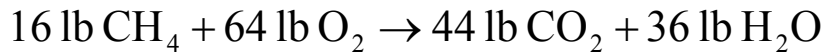
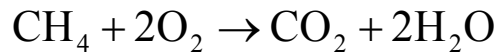
- 1) the clean fuel is methane available at 20 psi from a pipeline
- 2) oxygen plant provides oxygen at 25 psi
- 3) carbon dioxide leaves the plant at 20 psi.
- 4) a gas turbine derivative steam turbine, not limited by the 1100 F allowable temperature of economic boiler piping, can be designed for operation at temperatures up to 2300 F.
- 5) not more than 3 feed water heaters can be used
- 6) Clean Energy Systems Gas Generating and Reheating equipment listed below can be used
- 7) centrifugal compressor stage pressure ratios can not exceed 2.5
- 8) reciprocating compressor compression ratios can not exceed 15.
- 9) The oxygen plant requires air to be compressed to 105 psia and the oxygen plant can recover 90% of the oxygen in the compressed feed air.
- 10) Carbon dioxide must be compressed to 1.3 times its critical pressure for sequestration injection.

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The program EES is ideally suited to the study of cycle improvements.

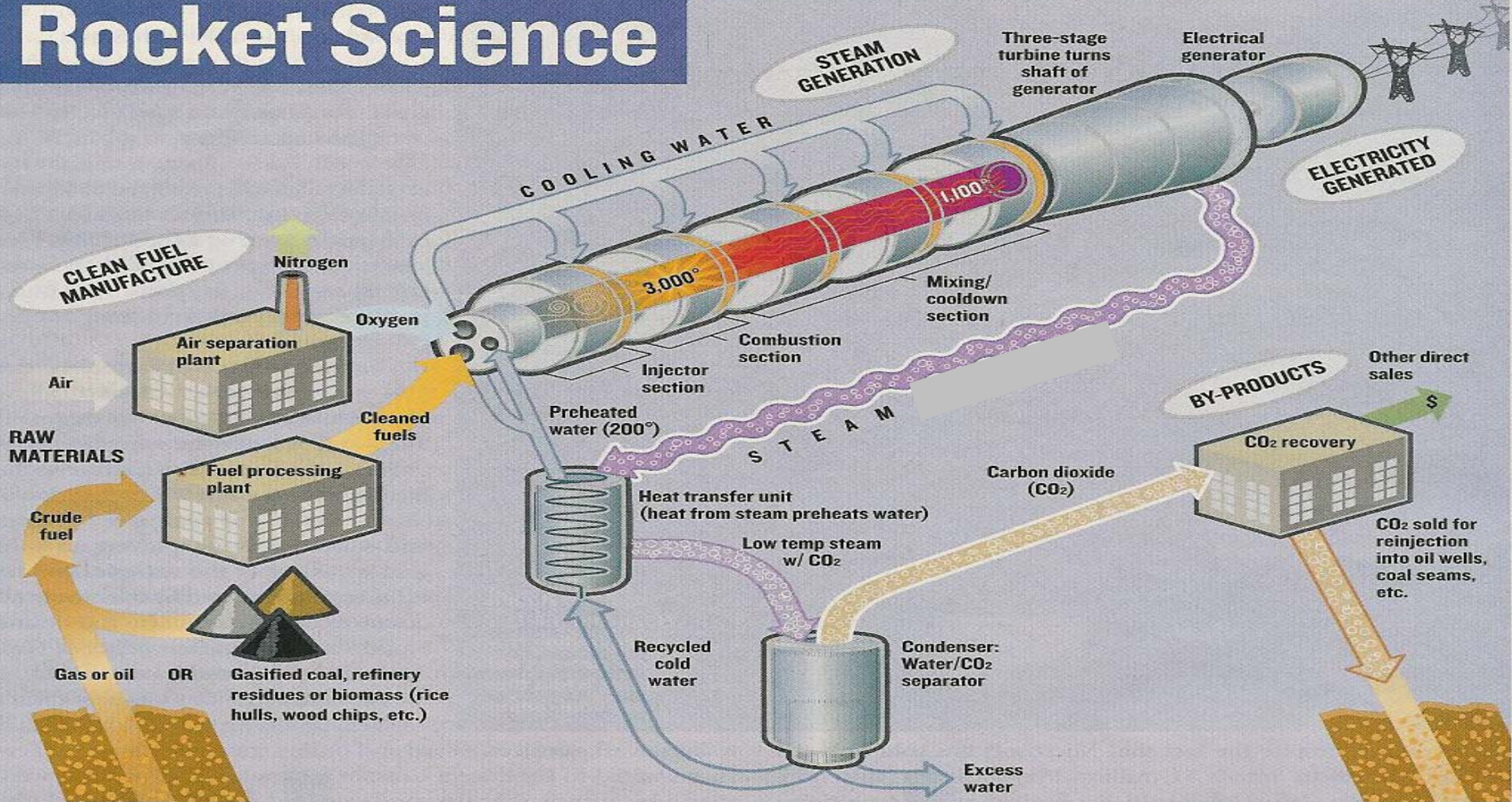
A schematic of your improved process, T-s property diagrams and an outline of your report are due November 13. The Final Reports is due November 27. Each student is required to investigate cycles, execute this design problem and write a report as an individual. Identical reports and reports from groups of students will not be accepted.

For the "cleaned fuel" methane, complete combustion of the fuel follows the equation :



In the Cengel and Boles text book the properties of water are available up to 2000 F in Table A - 6E and the properties/ lb mole of watervapor are available up to 5300 R in Table A - 23E. The properties of water are available up to 1835 F at the NIST website.

Rocket Science



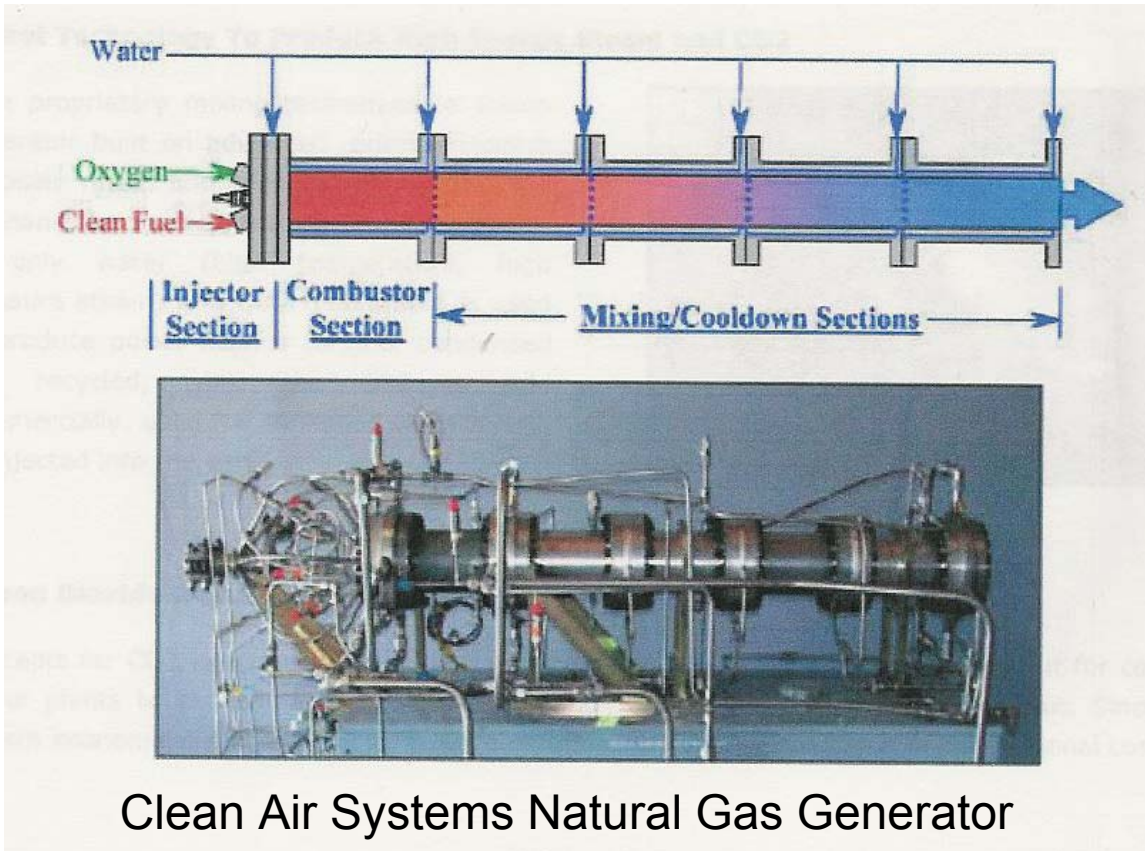
Can you make a greener power plant out of a rocket engine? Clean Energy Systems, a small firm in Sacramento, Calif., says it can. The idea is to strip carbon dioxide—a greenhouse gas—out of the smokestack. In a conventional fossil-fuel plant that's prohibitively expensive, since the CO₂ is mixed in with nitrogen. Clean Energy separates the nitrogen before, not after, combustion. The oxygen

that remains is burned with fuel and water in a chamber modeled after a rocket engine. The output is a hot, high-pressure mix of steam and CO₂ that powers a turbine. Too hot, as it turns out: The gas stream has to be chilled to 1,100 degrees Fahrenheit before hitting the turbine blades. The recovered CO₂ is sent down pipelines to be reinjected into oil and natural gas wells. A demonstration plant will

be running next year, but economic hurdles remain. One is that a modest 70-megawatt plant would require a \$60 million air separator. Another is that, until turbines are built to withstand 3,000-degree steam, a fair amount of the fuel's energy is wasted. The rocket engine power plant runs at a 35% thermal efficiency, versus 55% for conventional gas-fired plants.

—Daniel Fisher

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Properties of water vapor at 3000 F based on $h = 0$ at $x = 0, T = 32F$

p	h	s
psi	Btu/lb	Btu/lb R
100	2737	2.431
500	2736	2.253
1000	2735	2.176
1500	2734	2.131
2000	2733	2.099
2500	2732	2.073
3000	2730	2.053

Clean Air Systems has demonstrated a natural gas driven steam generator which provides water vapor and carbon dioxide at 1500 F and 1500 psi and a natural gas driven reheater that provides water vapor and carbon dioxide at 2200 F and 145 psi.