Advanced Brayton cycles with CO_2 capture and H_2 coproduction

OVERVIEW

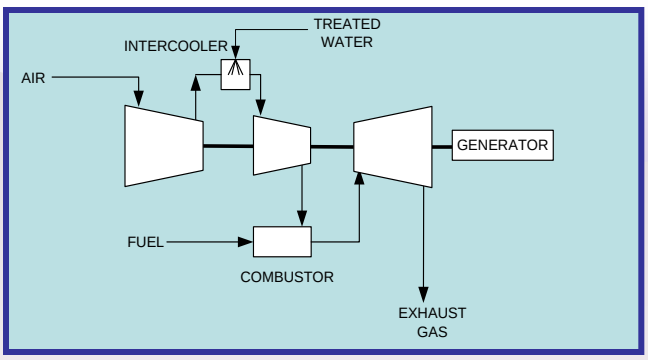
CO_2 is the primary constituent in the earth's atmosphere that contributes to the greenhouse effect. In addition to CO_2, pollutants such as oxides of sulfur and nitrogen, CO, unburned hydrocarbons and Hg are introduced into the atmosphere when traditional power generation technologies relying on combustion are used. Criteria pollutant emissions may be minimized from a coal fueled power plant by converting coal to a fuel gas (synthesis gas or syngas) by partial oxidation (or gasification), cleaning up the gas and then combusting it in gas turbines. CO_2 generated from a given fuel source per unit of power produced is inversely proportional to the plant thermal efficiency for a given carbon conversion. Advanced Brayton cycle concepts with high thermal efficiency are required for deployment in such a power plant (also known as an integrated gasification combined cycle or IGCC) to reduce the cost of generating electric power while reducing the environmental impacts of fossil fuel usage. Co-gasification with biomass, an essentially carbon neural fuel can reduce the net CO_2 introduced into the atmosphere while further decreases in CO_2 emissions may be realized by separating and capturing the CO_2 for sequestration before the gas is combusted in the gas turbine for sustainable electric power generation.

GOALS

- Identify and assess advanced improvements to the Brayton cycle that will lead to significant performance improvements in coal based near zero emission power plants
- Identify and assess advanced subsystem technologies to coproduce H_2 as a transportation fuel
- Identify and assess advanced CO_2 separation and capture subsystem technologies

RESULTS

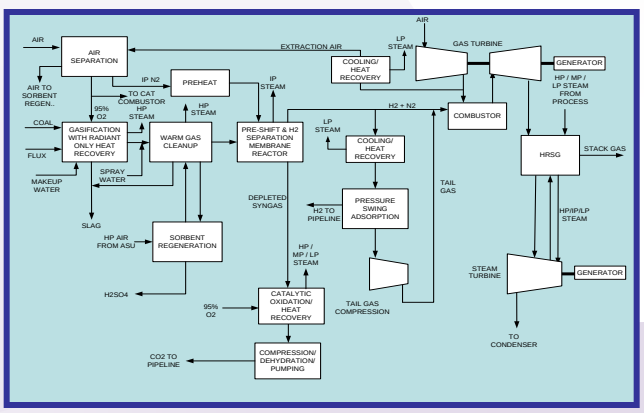
The promising advanced cycle identified was a closed circuit steam-cooled intercooled gas turbine (with nominal rotor inlet temperature of 1700°C) and pressure ratio of 50 to limit exhaust temperature. Spray intercooling which has commercially proven in a land-based aero-derivative gas turbine and has the advantage of lowering compressor discharge temperature results in savings in materials of construction, lower NO_x emission and higher specific power output. Resulting thermal efficiency of the plant at 38% (coal HHV basis) corresponds to ~9% reduction in heat rate compared to a similar plant using current state-of-the-art H-class gas turbine. Plant cost and cost of electricity for the advanced Brayton cycle based IGCC are about 8% lower than those using an H-class gas turbine. Major technological challenges identified for this advanced gas turbine are the combustor and turbine materials.



SPRAY INTERCOOLED GAS TURBINE

RESULTS (continued)

For H_2 coproduction, a H_2 separation membrane reactor (HSMR) produces H_2 by shifting the CO while simultaneously separating the H_2. Intermediate pressure N_2 from the air separation unit is used as sweep gas to assist in separation by decreasing partial pressure of the H_2 on permeate side. The non-permeate CO_2 rich gas after catalytic oxidation of residual combustibles is further compressed and pipelined for CO_2 sequestration. Pressure swing adsorption is used to purify a portion of the H_2-N_2 leaving the HSMR for export while remainder is supplied to gas turbines as decarbonized fuel.



COPRODUCTION OF ELECTRICITY AND H_2 FROM COAL WHILE CAPTURING CO_2

RECENT PUBLICATIONS/PAPERS

Rao, A.D., "Advanced Brayton Cycles for IGCC Applications," *presented at the International Colloquium on Environmentally Preferred Advanced Power Generation,* Newport Beach, California, February, 2009

Rao, A.D., D. Francuz, A. Verma, G.S. Samuelsen, "Integration of air separation unit with H_2 separation membrane reactor in coal-based power plant*," proceedings of the ASME IGTI Conference,* Barcelona, May 2006

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