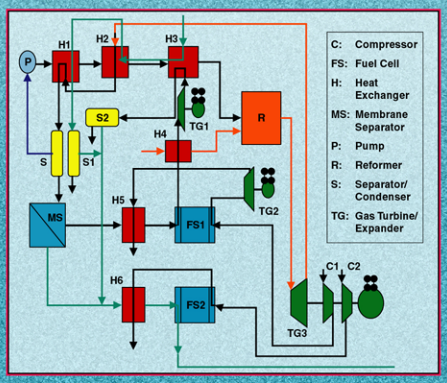
The LAJ Cycle: A New Combined-Cycle Fossil Fuel Power System

The LAJ* Cycle is a Gas Turbine–Fuel Cell Hybrid



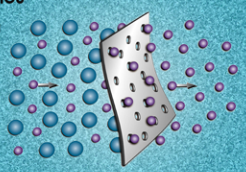
- High-pressure reformed natural gas or coal-derived synthesis gas is expanded in TG3
- Heated air is expanded in TG2
- Carbon dioxide is expanded in TG1
- After expansion, hydrogen and carbon monoxide are separated and used as fuel in fuel cells FS2 and FS1, respectively
- Three turbines contribute 13% of the total power output

*"LAJ" refers to the inventors, Labinov, Armstrong, and Judkins

High-Temperature Separation Provides Efficiency Advantages

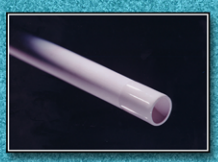
High-temperature inorganic membranes were selected for analysis

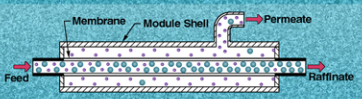
- Porous gas separation membranes
- Transport via molecular diffusion
- Separation by
  - Molecular sieving,
  - Knudsen diffusion, or
  - Surface flow
- 5-Å pore diameter membranes
- Very high permeance (0.14 cc/min/cm^2/cm Hg at ~500°C)



Several performance criteria have been met

- 90% of hydrogen at >90% purity
- 1600-psi burst pressure
- 600°C temperature capability (depending on material)
- Composite structures (membrane on porous support)
- Metals on metals, metals on ceramics, ceramics on metals, ceramics on ceramics, carbon on metals, carbon on ceramics

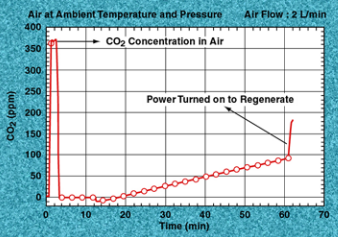


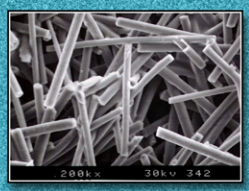


Separation Module Using Molecular Sieve Membrane to Separate Gases

Effective H_2 – CO Separation Is Critical

- Low-temperature separation, used for gas separation and purification, is based on electrical swing adsorption
- An activated-carbon-bonded carbon-fiber composite adsorbent was selected
- Operation is limited to <100°C
- Low-temperature operation imposes some efficiency penalty





Fuel Cell Options

Fuel Cell Type	PEM	Alkaline	PAFC	MCFC	SOFC
Electrolyte	Polymer	Potassium Hydroxide	Phosphoric Acid	Molten Carbonate Salt	Y-Stabilized Zirconia
Operating Temperature (°C)	5–90	50–100	160–220	650	800–1000
Fuels	H_2	H_2	H_2	H_2	H_2, CO, CH_4, C_4H_{10}
Reforming	External	External	External	External/ Internal	External/ Internal
Efficiency (% HHV)	50–60	50–70	55	55–65	55–65

The LAJ Cycle Has Several Desirable Attributes

- The LAJ cycle is capable of achieving a conversion efficiency (fuel chemical energy to electricity) of over 70%
- System power can be decreased by approximately 20% by disconnecting gas and air expanders
- It is only possible to decrease the system output power by more than 20% by decreasing the fuel cell power
- Nitrogen oxides are not formed in exhaust gases under the system's maximum working temperature
- Carbon dioxide is isolated as a separate flow stream. This facilitates its separation and capture as well as the integration of the system with various sequestration options

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